SYSTEMS BEHAVIOUR OF A PERISHABLE COMMODITY INDUSTRY - AN INDUSTRIAL DYNAMICS APPROACH

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CERTIFICATE

This is to certify that the work "Systems Behaviour of a Perishable Commodity Industry - An Industrial Dynamics Approach" by Som Nath Kapoor has been carried out under my supervision and that this has not been submitted elsewhere for a degree.

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The only page where a man can jot down his own thoughts without a raised eyebrow, I take the first opportunity to express my indebtedness to Dr. J.L. Batra who has been a constant inspiration and a guide in the completion of this work.

I have to make a mention of so many of my friends - in particular Mr. Rajagopalan, who have always been there with help and valuable suggestions at times of depression.

Lastly, I thank Mr. Uma Raman Pandey for taking pains to type the manuscript patiently and neatly.

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"Systems Behavior of a Perishable Commodity Industry-An Industrial Dynamics Approach"

In this study an Industrial Dynamics approach for studying the systems behavior of a perishable commodity industry is presented. A detailed model, incorporating the various sectors - agriculture, cold storage, juice processing factory and market, has been formulated taking into account the inter-actions and the inter-dependences of these sectors. DYNAMO has been used as programming language for the simulation of the system. Various decision rules and the sensitivity analysis of various parameters has been studied.

CHAPTER I

INTRODUCTION

Mathematical literature today abounds with optimisation and related techniques. The mathematical sophistication attained so far helps analyse only relatively small systems. As the boundaries are relaxed, the system becomes complex and it may not be possible to optimise the same. However, an attempt can be made to study the system behaviour in order to comprehend the system better. Industries in general are quite complex systems with their inter-actions and controlling forces within. Commodity industries in particular are most prone to price and demand fluctuations which have proved an enigma to most of the business pundits; the complexity enhanced due to competition and inherent instability. Agricultural products and natural resources can well be cited as illustrations to the point.

Added to all this is the perishable nature of agricultural products bringing to the fore problems of wastage, quality deterioration etc. Fruits form the bulk of these perishable products.

In light of the above, the problems faced by an orange industry were taken up for the present investigation. A system study of the whole industry is attempted in order to gain an insight into the pertinent parameters and design variables etc. An attempt has been made to enlarge the boundaries as

far as possible so as to include the agricultural sector, processing sector as well as marketing.

The importance of the fruit growing industry is more than apparent with the government paying more and more attention to it. A number of orchards have been set up and technical guidance is being provided to the needy. Oranges come under the general caption of citrus fruits occupying about seventy percent of Citrus fruit growing area. Furthermore, orange has gained wide popularity for its flavour and more so for its nutritious value. Thus it would be safe to presume that orange industry may gain prominence in the near future.

The advent of simulation and more so Industrial Dynamics has opened up new avenues for wide and realistic studies. Industrial Dynamics can account for as intricate and complex systems as possible. It is not a method of solution but an awareness that a business institution can be looked upon as a combination of levels, rates, feed-back loops and policies. Once the identification is complete the system can be simulated to gain an insight into the behavior and the effect of various policies on it. The management would now be wiser, and in a position to know in advance the effect of the policies to be implemented in contrast to the almost blind experimentation.[7]

The use of Industrial Dynamics as a method of analysis as contrasted to any other technique stands justified on the

following grounds :

1. With Industrial Dynamics techniqueit is relatively easy to model qualitative behavioral relationships.
2. Industrial Dynamics is based on the theory of feedback control systems; using the technique precludes the problems of structural incongruity.
3. Empirical data were not available sufficiently to permit use of statistical techniques for deriving some critical market relationships (e.g. retail price, elasticity, consumer demand due to advertising). However, the Industrial Dynamics methodology does not insist upon such data availability, although added confidence in the model formulation does result when derivation of relationships can be enhanced by statistical analysis methods. When these data are unknown, Industrial Dynamics offer the advantage of providing an easy vehicle for testing the sensitivity of company performance to deviations from the initial estimates made.
4. The relatively low mathematical sophistication required by the Industrial Dynamics approach enhances managements understanding of the system analysis effort. In the area of policy formulation it is likely that such increased understanding will

have direct and immediate result which would otherwise consume much more time before any change in managerial understanding is reflected clearly in company policy and performance.

To summarise the present investigation deals with the orange industry as a whole, taking into consideration the interactions at various stages from planting to marketing. Feed-back control concepts have been used to advantage, as an aid to making or modifying decisions from time to time. A computerised model has been proposed for the above using dynamo-language. Validation is done on the basis of available data and also through discussions.

Once, the validation is complete, system simulation can be attempted in order to study and record the behavior as an aid to managerial decision making.

CHAPTER II

GENERAL DESCRIPTION OF INDIAN ORANGE INDUSTRY

Commodity industries are, in general, plagued by the continuous price fluctuations; the orange-industry being no exception. To what extent it is due to managerial practices within the industry and the disturbances without, is to be investigated. A general opinion prevails that fluctuations in demand at the retail shops transmit itself to the higher echelons of the industry. Contrary to this is the belief that even with a stable demand, there would still be these fluctuations. The shortcomings of the organisational structure and the lack of combinatorial objectives coupled with inherent uncertainty in any industry may bring about these instabilities.

In a commodity system, the commodity is not produced to the specific order of the customers. The producer usually is not in a position to stockpile the commodity for long periods of time and delivers his output to the market as it is produced. The stock holder purchases, from the primary source of supply, all that is offered to him. The effect of price fluctuations on supply rates is damped, as well as time lagged. A glut in the market, resulting in fall in the prices, may find some producers unable to operate profitably and eventually curtail production. On the other hand, others continue production in the hope that prices will recover. In fact, extra production

is resorted to, in order to mitigate the losses. However, sustained losses force business failures, bringing about the required curtailment of production.

The changes in price propagate downwards throughout the industry, eventually dictating the demand. The production on the other hand is also suitably stimulated. The effect of such price changes may not be felt on the demand and the production instantaneously. In fact it may so happen that because of the time lag, demand and production may not be able to reach the equilibrium condition for a long time to come. Added to all this, the speculation and hoarding at all levels may accentuate the system instability.

In India, more than 90% of the orange crop is sold in the raw fruit market for direct consumption. The prices in raw fruit market swing widely. Short term fluctuations in price of raw fruit market are apparently caused by the uncertain weather conditions, etc., in that the industry is unable to predict the size of the crop. A severe freeze can reduce the orange crop by as much as 20%. Processors, expecting to charge higher prices for the concentrate, owing to the reduced supply, bid up the price of the raw fruit. If good weather persists throughout the growing season, then the yield will be greater than expected, which drives the fruit and concentrate prices downward. On an average, the weather conditions may affect the yearly yield of oranges by 5% to 10% keeping the industry and prices in a constant state of uncertainty and fluctuations.

For longer horizons (two-three years), the prices of the raw oranges are primarily determined by the inter-actions of demand and supply over the same period. If the long run orange yield is high, supply of concentrate is in plenty, resulting in lower prices at the retail-stores and vice-versa. The demand of processed forms is determined by the price set up at the processing unit as the retailers merely take their marketing charges.

While long run price of concentrate is controlled by the long run supply of raw fruit, short term fluctuations also exist. The price of concentrate is (apparently) based upon the inventory of the concentrate held by processors. Since the retailers keep only enough of the concentrate on hand in order to meet two or three weeks of demand, the remaining inventory of the concentrate has to be held by the processors. The inventory of the concentrated juice at the processing unit may be quite large, since the annual crop of oranges must be concentrated between December to June, while retail sales continue throughout the year. At the end of harvesting season in June, the processors accumulate a large inventory to meet the demand for the concentrate until the next season crop begins to be concentrated in the next December.

2.1 Cultivation and Distribution of Oranges :

Citrus fruits rank third (next to grapes and olives) in acreage among the sub-tropical fruits of the world, and

India ranks sixth among the Citrus growing countries (24). In India citrus fruits occupy an area of 0.22 million acres out of the total area of 3.09 million acres under all fruits (18). Mandarin or santra is one of the sixteen species of Citrus fruits. This is a loose skin orange and its agricultural name is Citrus reticulata. It is widely cultivated in all subtropical regions. The principal regions of Citrus cultivation in India lie in Assam, Sikkim, Central Provinces, Punjab and Coorg. Commercial production in Central Provinces is centred in Nagpur, Bhandara, Wardha, Chinwada and Amravati districts. In South-India, mandarin is cultivated on a large scale in Coorg (24).

The area under loose-skinned oranges in India is estimated at 65000 acres. Central-Provinces lead with about 20000 acres followed by Coorg, Assam, Punjab and Bombay. Mandarin is the most valued commercial orange of India. The fruit is used mainly as dessert and in processed form e.g. juice, squash, jam, etc. Citrus -Sinesis, a tight skin orange (also known as sweet orange or mousambi) is another common species of Citrus fruits (24).

Propagation : Citrus trees are readily propagated by seeds, cuttings, layering and budding. Almost the entire area under Citrus in Assam and South-India are planted by trees raised from seeds. Budding is becoming more common, as budded trees bear fruit at an earlier age and produce fruits of uniform size and quality.

The budded trees of santra orange begin to bear small crops from the fourth year onward but normal crops are borne from the seventh year. The fruits mature after about nine months of their blossoming. The seedling trees of santra usually come to their maiden bearing in the eighth year and to regular bearing from the tenth year onwards. Due to varying climates, the harvesting periods differ in different parts ofthe country. Budded trees of mandarins give a commercial crop in about seven years. The life of budded trees is about 35 years and of seedling's about 60 years (18).

<u>Harvesting</u> : Mandarins should be harvested as soon as it is ripe. Loose skinned oranges produce two crops a year, with a variable third crop in some seasons in South-India. Three blooming periods are also recognized in Central and Western India. In Coorg, the main crop is harvested during January-February and constitutes 90% of the annual production and the off season crop from July to September with a small third crop in March to April. This also applies to parts in Mysore and Wynaad (9).

Like the Coorg mandarins, Nagpur mandarin oranges also blossoms twice a year in the Nagpur region. The blossoming of June-July is called 'mrig-bahar'. The resulting crop begins to ripen in February but harvesting continues till the end of April. The second flowering occurs in December-January and is known as 'Ambia-bahar'. The fruit of this flowering is ready in September and is harvested till the end of November. About

70% of annual production of 'Nagpur' orange is obtained from the 'mrig-bahar' which forms the main season crop and the remaining 30% from the 'ambia bahar', the second season (9). Some variations in the above periods are found in the literature on oranges. Harvesting seasons for other places will not be discussed here as most of the orange crop comes from these two areas.

Citrus fruits have to be picked up when they have developed their characteristic flavour to the maximum extent. The optimum maturity stage for harvest is difficult to determine. It is customary to harvest fruits in India according to the prevailing demand, and this often leads to the mixing up of good and poor quality fruits, and mature and immature fruits in the same lot. Citrus fruits should not be picked up during rains or for a few days after, or when the fruits are covered with dew (24).

Yield : The average yield of mandarins varies from 2300 to 4500 kg/hectare (23). In Vidharbha, the yield of 'Nagpur' santra is 10,000 kg/hectare while record yield upto 23000 kg/hectare has also been reported (23). In good orchards the average yield per tree may range from 1,000 to 1,500 fruits. In Coorg and Wynaad the average yield per hectare is about 14,000 kgs and maximum yield of 5,000 fruits per tree per annum is recorded (24).

Yield of santra varies from 50 to 250 Mds. per acre. The yield of Nagpur santra is 110 mds. per acre while the maximum yield recorded is 250 mds. In Coorg and Wynaad, average yield per acre is about 150 mds. and maximum yield recorded is 5000 fruits per tree (24).

Ranjit Singh (18) reports an yield of 4100 to 30,000 lbs. per acre and a good mandarin tree bears about 1000 to 1500 fruits.

Year Production : Production of mandarins for the last twenty years is summarised below (15) :

Years	1948-52	1961-65	1966	1967	1968	1969	1970
Production (1000 m-Tonnes)	226	696	800	900	900	900	900

Storage : Santra is quickly perishable compared to sweet oranges and lose freshness, shrink and become stale within a week after harvest (23). The storage in the warmer seasons is more important and ripe santra can be stored at 40°F for three months (18). Grower can regulate the prices during the glut season in the market period by keeping oranges in cold-storage chambers at low temperatures.

Inter-State Trade : There is considerable inter-State trade of oranges. Large quantities of 'Nagpur' oranges are sent to markets all over India from Nagpur. Coorg oranges are mainly exported to places in Madras and Mysore. An idea of inter-State

trade can be had from the following table (Ref.24) :

Export of Nagpur Oranges

Importing Station	Quantity (in Maunds)
Calcutta	2,21,250
Delhi	92,250
Madras	63,750
Bombay	36,750
Other stations	2,53,500
Total -	4,67,400

Prices : Orchard prices of Citrus fruits are settled either on acreage basis or on the basis of weight or count of fruit picked. Whole-sale prices of oranges vary to a considerable extent in different markets during different parts of the season according to demand and supply. Prices rule high at the beginning of the season due to limited supplies; they decline as the season advances and supplies increase, and show an upward tendency towards the end of the season when supplies dwindle (Table 2.1). All the juicy fruits have more demand during warmer months.

Citrus Products : Citrus fruits are esteemed primarily as articles of diet. They also provide a large number of commercial oils, Citric acid and pectin. Fruits which are not consumed for table purposes are converted into beverages (juice, squashes, and cordials), marmlades, and jellies.

Table 2.1

Average wholesale price variation (per 100 oranges) in different markets in India in 1949 (Ref. 24)

	Calcutta (Nagpur Santra)		Madras (Sathgudi medium)		Nagpur		Kanpur	
	(Rs.	An.)	(Rs.	An.)	(Rs.	An.)	(Rs.	An.)
January	3	15	9	10	1	9	5	3
February	3	5	17	4	1	10	3	12
March	6	4	8	0	1	9	3	12
April	10	8	11	3	2	12	5	11
May	14	8	12	0	5	13	10	7
June	13	15	7	4	-	-	-	-
July	18	7	7	7	-	-	-	-
August	25	0	8	0	-	-	-	-
September	6	12	9	14	-	-	-	-
October	8	4	5	12	-	-	-	-
November	8	11	5	0	-	-	-	-
December	5	11	7	0	-	-	-	-

The composition of mandarin oranges is as follows :

Peel - 35%, Juice - 50%, Marc - 13%, Seed - 2% (Ref.24).

Juice - Citrus juices are important articles of diet. The sugars, acids and essential oils present in them determine their quality. Citrus juices can be preserved not only as liquid concentrates,

but also in solid form as powders.

Citrus peels constitute a valuable source of essential oils and pectins. Mandarin oil is an orange coloured liquid obtained by extraction from the peels of Citrus reticulata (24).

CHAPTER III

A BRIEF REVIEW OF INDUSTRIAL DYNAMICS

Industrial Dynamics (I.D.) is the science of simulating the flows of orders, materials, money, personnel, capital equipment and information in a large organisation. The method was developed by Prof. J.W. Forrester and was first described in detail in his book "Industrial Dynamics"(3). The objective of the Industrial Dynamics study is to examine the implications of the policies in a large organisation when they are all placed in a single model and allowed to interact. Forrester defines it as :

"Industrial Dynamics is the study of the information-feedback characteristics of industrial activity to show how organisational structure, amplification (in policies), and the delays (in decisions and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel and capital equipment in a company, an industry, or a national economy"(4).

3.1 Systems Concept :

The importance of systems engineering has been recognised over the last three decades or so. Forrester describes it as :

"Systems engineering is a formal awareness of the interactions between the parts of a system. A telephone system is not merely wire, amplifier, relays and telephone sets to be considered separately. The interactions, the compatability, the effect of one upon the other, the objectives of the whole, the relationship of the system to the users, and the economic feasibility must receive even more attention than the parts, if the final result is to be successful"(4).

Forrester emphasises the importance of systems concept in management as well :

"Our industrial systems are becoming so large and complex that a knowledge of the parts taken separately is not sufficient. In management as in engineering, we can expect that the interconnections and interactions between the components of the system will often be more important than the separate component themselves" (4).

Industrial Dynamics can be applied to a wide variety of organisational activities like production, distribution, accounting, capital investment, research and development, etc. It provides a single framework for integrating the functional areas of management mentioned above. It is a quantitative and experimental approach for relating organisational structure and corporate policy to industrial growth and stability. By 'experimental', it is meant that models formulated in Industrial Dynamics are a mathematical replica of the structure of the real system, including the flow of money, men, materials and information and the location of decision points.

Subsequent to the model formulation, the system is simulated as a whole in order to study the different characteristics with respect to time.

Based on the primary assumption that decisions in management and economics take place in a framework that belongs to the general class known as information-feedback systems, Forrester has developed a method of analysis and simulation technique for large and complex systems that conformed to the well defined and established theory of feedback

control systems (12).

Forrester (7) discusses Industrial Dynamics as a tool in the study of the managerial decision-making process. It enables the design of more effective industrial and economic systems. Roberts (20) proposed Industrial Dynamics both as a philosophy and a methodology for organisational control system design. Roberts (21) was successful in overcoming the problem that had plagued many research efforts in the simulation of large complex systems i.e. defining the intangible variables as also measuring its effects with the help of Industrial Dynamics e.g. measuring such effects as the 'influence of willingness to accept risk by the customer' and such variables as the 'realised technical effectiveness by the customer'.

Llewellyn (10) describes Industrial Dynamics as "... a servomechanism, the emphasis being on studying its dynamic behavior rather than on optimising it as a system"; Dynamic behavior as, "... the core of Industrial Dynamics theory is that such a steady state seldom exists". This is in direct contrast to O.R. techniques where steady state conditions rather than transient ones are analysed. Llewellyn also talks of the difficulties of realising a steady state systems in practice

It has been found that the oscillating nature of the flow may be due to the policies rather than the external disturbances. New policies may be implemented which may give more stable performance (10).

According to Llewellyn (10), Industrial Dynamics is concerned with policy formation rather than with decision making. It focusses its attention not on how a particular decision is made at a particular time and under a given set of circumstances, but on how decisions made repeatedly according to a stated policy affect the performance in the long run and, particularly; on how they interact with other policies under the control of management.

3.2 Status of Feedback System Theory :

The basic structure of a feedback system is a loop. The system condition provides an input to a decision process that generates action. This action modifies the system conditions. It is thus a continuously circulating process. All types of decisions, whether they are personal, corporate, national, international or in environment fall within such a context (5).

The feedback systems have following four characteristics -

1. Order
2. Direction of feedback
3. Nonlinearity
4. Loop multiplicity

The number of levels (which are nothing but first order difference equations or integrations) in an I.D. model is equal to the systems order. While most of the literature on feedback systems deals with first and second order systems, even elementary managerial phenomena usually require a minimum of fifth to twentieth

order for adequate representation. The direction or the polarity of the feedback loops can be positive or negative. In positive feedback system an action increases a system state to produce still more action. It is an essential process in the growth of products, companies or countries, whereas the negative feedback loop is goal seeking, which may or may not be attained. 99% of the feedback systems literature deals with negative feedback, but all the processes of growth are manifestations of positive feedback. The degree of nonlinearity implies the number of policies in the system that are nonlinear. Throughout our social systems, nonlinearity dominates behavior. Finally to represent adequately managerial systems one must incorporate a number of major loops, each of which may contain many minor loops. (5)

As one moves toward systems of greater complexity in any one of the preceding dimensions - order, inclusion of positive feedback, nonlinearity and multiple loops - it is found that the representation and analysis of the systems behavior becomes very complex and known quantitative methods cannot be used to solve the problem. (5)

The behavior of the simpler systems cannot be extended for the prediction of complex systems behavior. Frequently a manager encounters this (non-linear, multiple loop systems of high orders) in actual practice, where a major policy change aimed at correcting a corporate problem seems to produce almost no result. Within a model of complex system one discovers orderly processes

which are responsible for defeating attempts at changing its behavior. Some of the most useful insights to come from Industrial Dynamics show which policies in system have enough leverage so that by changing them one can hope to alter systems behavior.(5)

Industrial dynamics stresses the feedback-loop structure of a system. The feedback loop constitutes a 'fundamental system building block' (5). To start with, a decision is taken to influence the state of a system. The resulting state in turn acts as an input at the same decision centre. Assumptions which are in contravention to the loop structure of system belittle its managerial significance.(6)

Ansoff and Slevin (1) do not accept Forrester's point of view that all industrial systems are inherently information feedback systems. ".... it does not necessarily follow that all aspects of the firm are best studied by means of information feedback systems"(1). They suggest that "the appropriateness of information feedback view point should be determined on the basis of the relative influence of the feedback information on the decision in any given situation"(1).

Forrester refutes the above observation with the help of an example (6). Various critics have asked that the generality of feedback loop structure be proved. To this Forrester says that, "This class is not subject to positive proof. Once the examples are given, the only possible proof is negative. If one can show an important and purposeful decision which is

not imbeded in a feed back loop structure then the generality is destroyed (6).

A simplified feedback model of a production distribution system is shown in Fig. 3.1. (For the flow diagram symbols, refer to Appendix A). The solid lines in the block diagram represent flows of material, the dashed lines represent flows of information and rectangular boxes represent storages of material or information. For simplicity cash flows and other assets or manpower and other resources are not included in the diagram, although such factors can be incorporated into such a model without conceptual difficulties. At the decision-points information regulates the rates of flow of material.

A system can be thought of as a pipe line net work containing some storage tanks. In effect the control decisions regulate the opening or closing of valves in the pipe line, thus decreasing or increasing the rates of flow into and out of the storage tanks. The important feature of such a system is that it can be described in terms of three main elements : storages, flows and decision regulating the flows.

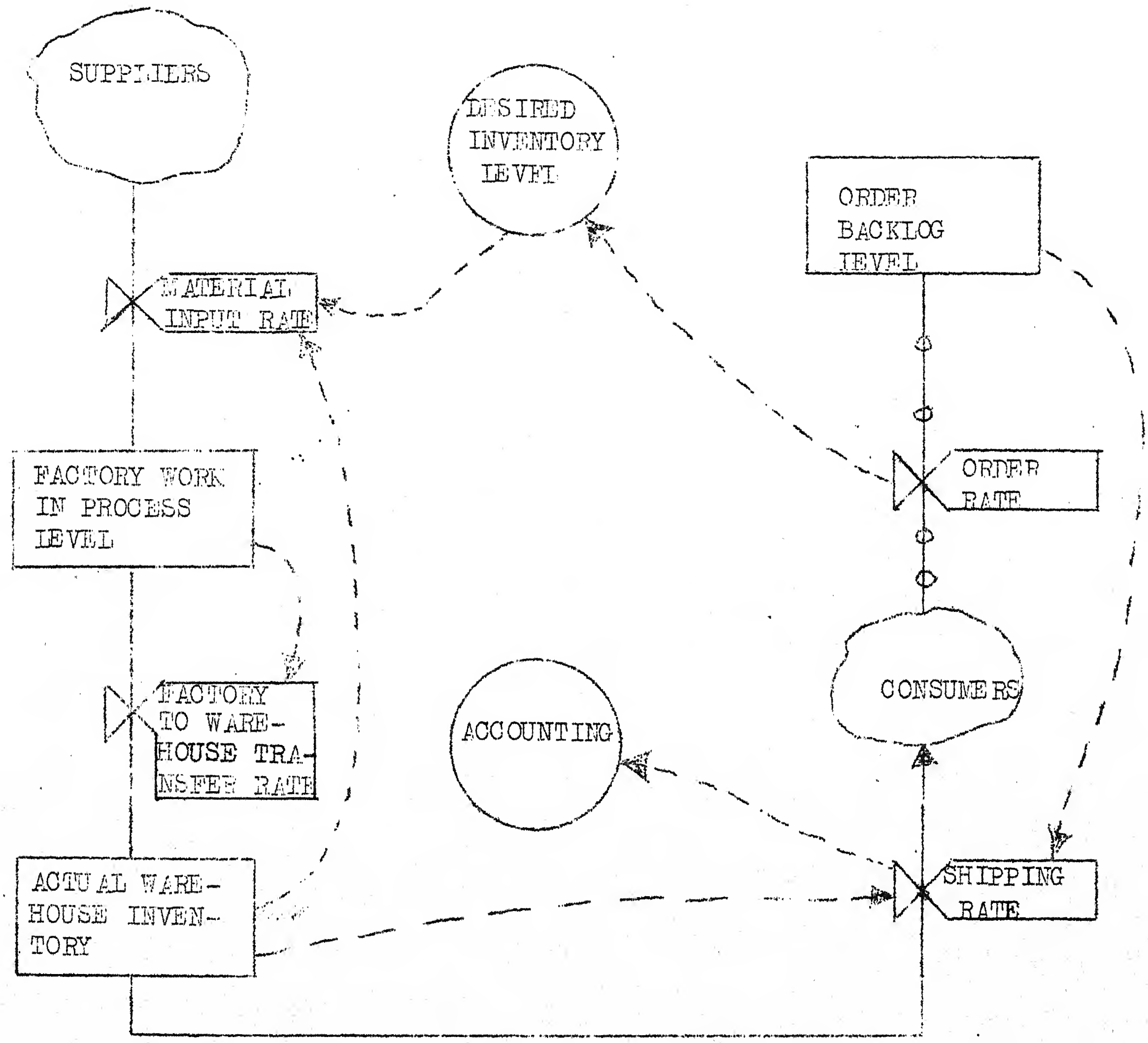


FIG.3.1 : A SIMPLIFIED FEEDBACK MODEL OF PRODUCTION-DISTRIBUTION SYSTEM

3.3 Industrial Dynamics as a Theory of Structure :

A system investigation aims to study its structure and its dynamic behavior. The two are interwoven because it is the structure which produces the behavior, "I.D. is a philosophy of structure in systems"(5). Industrial Dynamics embodies principles which relate structure to behavior. Listed below are the elements of a structure in heirarchial order :

1. Closed boundary
2. The feedback loop as the basic system component
3. Levels (the integrations of rates or accumulations of flows or states of a system) and Rates (the policy statements or activity variables or flows)
4. Policy structure

3.3.1 Closed Boundary -

Closed systems are an integral part of Industrial Dynamics. The boundary of such a system encloses all the elements necessary to give it the intrinsic character. The system has a dynamic independence in the sense that the environment is independent of any internal activity. The boundary of such a system is defined on the basis of following considerations : If one is interested in a particular mode of behavior the boundary must necessarily enclose these elements responsible for it. Thus for an industrial system, the boundary should and must enclose those particular aspects of the market, the competitors and the environment which are just sufficient to produce the behavior

under investigation.(5).

3.3.2 Feedback Loops -

Apart from the boundary, the system is observed to be a network of feedback loops. One or more of the loops are responsible for any single decision within the system. These loops interact to produce system behavior.(5).

3.3.3 Levels and Rates -

Levels are the variables generated by integrations of rates which at any instant define the state of a system and carry the continuity of the system from the present towards the future. Rates are the flow variables that are in turn dependent on the levels. The level and rate variables form a necessary and sufficient substructure of a feedback loop.(5)

3.3.4 Policy Substructure -

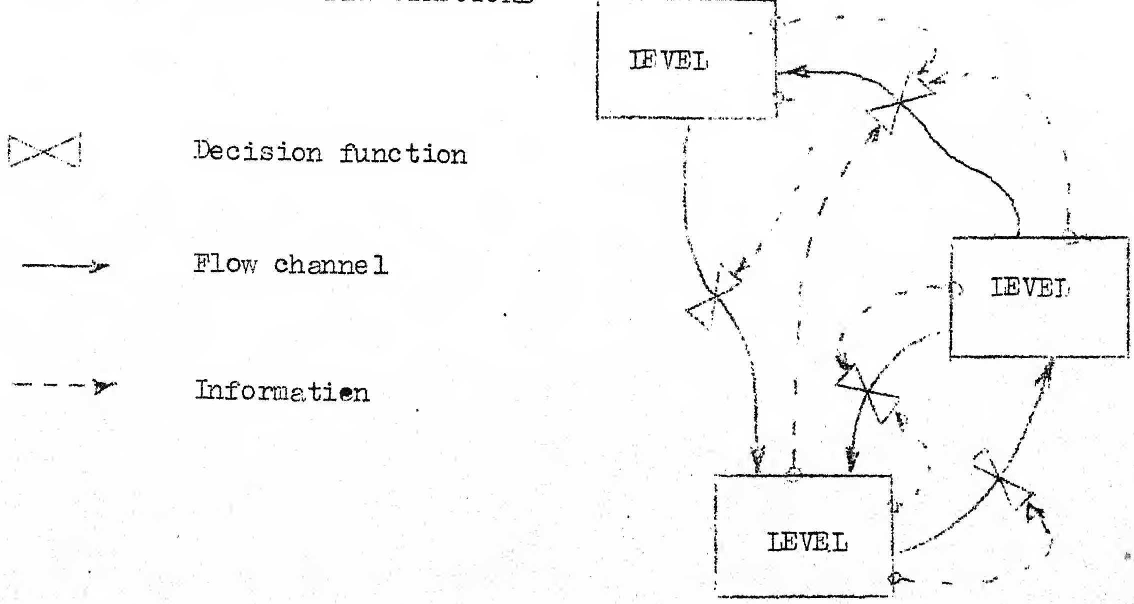
Whereas levels do not have any significant substructure except for the rates flowing into them, the rate variables do have an identifiable substructure. The rate equations are the policy statements in a system; the rules which determine the state of the system. A policy substructure consists of : (1) the goal of the decision making process, (2) information required for the decision making process or the observed condition, (3) the discrepancy between goal and observed condition and (4) the desired action to rectify the discrepancy.

A system structure designed on the above principles should be general i.e. applicable to all situations and be able

to organise knowledge in order to explain or alter some specific characteristic(s) (5).

A basic model structure, used in industrial and economic models, is shown in Fig. 3.2. It contains all the essential features of a model structure viz levels, flow rates, decision functions and information channels that connect the decision functions to levels. The levels and rates are an integral part of all the constituents of a system - men, money, material, orders, capital equipment and information

FIG. 3.2 : BASIC MODEL STRUCTURE



3.4 Validation of Industrial Dynamics Models :

Industrial Dynamics being relatively new science, it is felt that a few words be mentioned about model validation as applied to Industrial Dynamics models.

The significance of a model rests on how well it serves its purpose. The purpose of Industrial Dynamics models is to aid in designing better management systems. A model should be judged by the importance of the objectives to which it is addressed and its ability to predict the effect of system design changes. Validity of a model as a description of a specific system should be examined relative to the system boundaries, interacting variables and values of parameters. The dynamics of a system is in general relatively insensitive to most of the parameters. The few to which it is sensitive will be identified by model tests; the values for the rest may however be chosen any where within a plausible range. Confidence in a model arises from a two-fold test - the validation of component structures and acceptability of overall system behavior. The complete model must be judged on the basis of system behavior : stability, periods of fluctuations, timing relationships between variables, and fluctuation in amplitudes of system output - the variables that describe the general character of a system. The abrupt values of system-variables are closely related to the time phasing and periodicity. The details of the design can be validated by evidence and through arguments justifying the

structure of each equation, the selection of system boundaries, its variables and interactions assumed between them. If all the necessary components are adequately described and properly interrelated, the model of the system must behave as it should. To design and justify a model, it is necessary to have a comprehensive knowledge of the system. (4)

Actual industrial systems differ markedly in the rapidity with which changes occur in prices, production rates, order flows, and other variables. The model of a system should show the same transition characteristics as the system.

A dynamic system model should represent and predict the behavior (e.g. profitability, stability of employment and prices, growth techniques, and typical phasing relationships between changes in variables) of the actual system. The ability of a model to predict the state of the real system at some specific future time is not necessarily a sound test of model usefulness. (4)

Naylor and Finger (13) discuss the philosophy as well as methodology of the problem of model verification. The authors suggest a multistage verification procedure incorporating the methodology of rationalism, empiricism and positive economics. They further stress that the multistage verification is particularly applicable to the verification of computer simulation models of individual systems.

Forrester (4) suggests a qualitative method of verification. He argues :

> "We some times encounter the attitude that model validity can be treated only in a numerical and quantitative manner. This hardly seems justifiable when such a preponderant amount of human knowledge is in nonquantitative form ....
> .... if most of the content of a model is drawn from nonnumerical sources in the form of individual personal knowledge and verbal and written descriptions, the defense of the model will usually rest on the same kinds of knowledge".

Due to lack of formal quantitative procedure for the verification of the computer simulation model constructed here, the informal, qualitative method of verification suggested by Forrester (4) was employed. It is tried that the individual expressions in the model have meaning in context to the real system. All variables and parameters have conceptual meaning that can be individually considered with respect to the real system. They are then checked against past incidents and experiences, and considered from the view point of what they imply under both normal and extreme circumstances. Thus after a critical analysis, one can form an opinion on whether or not, a model suits its particular purpose. This should be considered as a necessary and sufficient requirement for model validation.

3.5 Applications of Industrial Dynamics :

Industrial Dynamics has wide and varied applications in managerial decision making. Closely treading the path shown by Prof. J.W. Forrester in his revolutionary concepts were many a workers who looked up widely diverse avenues for application and improvement.

Roberts et al (19) have applied Industrial Dynamics for investigating, understanding and experimenting with the process of goal achievements in a vertically integrated firm dealing with perishable goods. Butler (3) was also involved in studying perishable goods inventory but more from the point of view of marketing - demand, supply and prices. An econometric study on similar lines was conducted by Prato (14).

The authors mentioned above focussed on the importance of Industrial Dynamics as a tool for analysis and design of systems. The satisfactory results endorsed their claims. The above applications were mainly concerned with perishable goods.

Instances of application of Industrial Dynamics have been recorded in diverse fields as noted along with i) Market dynamics, (ii) Urban dynamics, iii) Models of entire industries, iv) Econometric studies, v) Research and development etc.

The present study is concerned with modelling of an entire industry - in particular a perishable commodity industry.

CHAPTER IV

MODEL FORMULATION

The model presented here is a simulation model, primarily concerned with the analysis and identification of pertiment variables and parameters. Initially the boundaries of the system to be analysed are ascertained and subsequently various subsystems are recognised. After identifying and defining the total system, its boundaries and sectors, attention is drawn to the functions of the individual sectors. This helps in building up a system simulation model which emphasises on the relationship of the subsystems to each other and to the system as a whole. Thus, the goal of the modeling process - a valid representation of the system being analysed - can be achieved.

In the description to follow, first a general view of the entire system is presented, followed by detailed descriptions of the individual subsystems or sectors of the model.

4.1 System Description :

The purpose of this work is to examine the impact of various decisions at different stages in an orange industry on the dynamic behavior of the system. Although in the model emphasis is given only on orange industry, the analysis is valid for other fruits as well e.g. apple, pineapple, mango, etc.

Fig. 4.1 shows the various sectors of the model and the relationships between the pertinent variables. The relationships between various sectors are represented by the "flows" connecting them. These flows tie together the material, information and decision components of the system structure. The flows could be : flow of men, material, money, information. These flows accumulate to form levels. Flows of information may be smoothed through a delay in action until the information forces an appropriate action. The level equations at any instant of time describe the condition or state of the system. The level variables carry the continuity of the system from the present toward the future and provide the information on which rates of flow are based. The rate variables which represent the decision f... tions of the real system are the activity or flow variables. These rates, change the value of the levels. Simplifications in the formulations of the rate equations are provided by the use of auxiliary variables.

To study the behavior of whole orange industry, the industry is divided into four sectors. Each sector in turn includes a number of stages. At each stage there are decision variables and state variables. The sectors with a description of variables and parameters are given below :

(1) The Agricultural Sector :

Variables - Planting rate, total annual crop, harvesting rate, sales rate to cold storage, total demand of oranges and price level, wastage of fruit

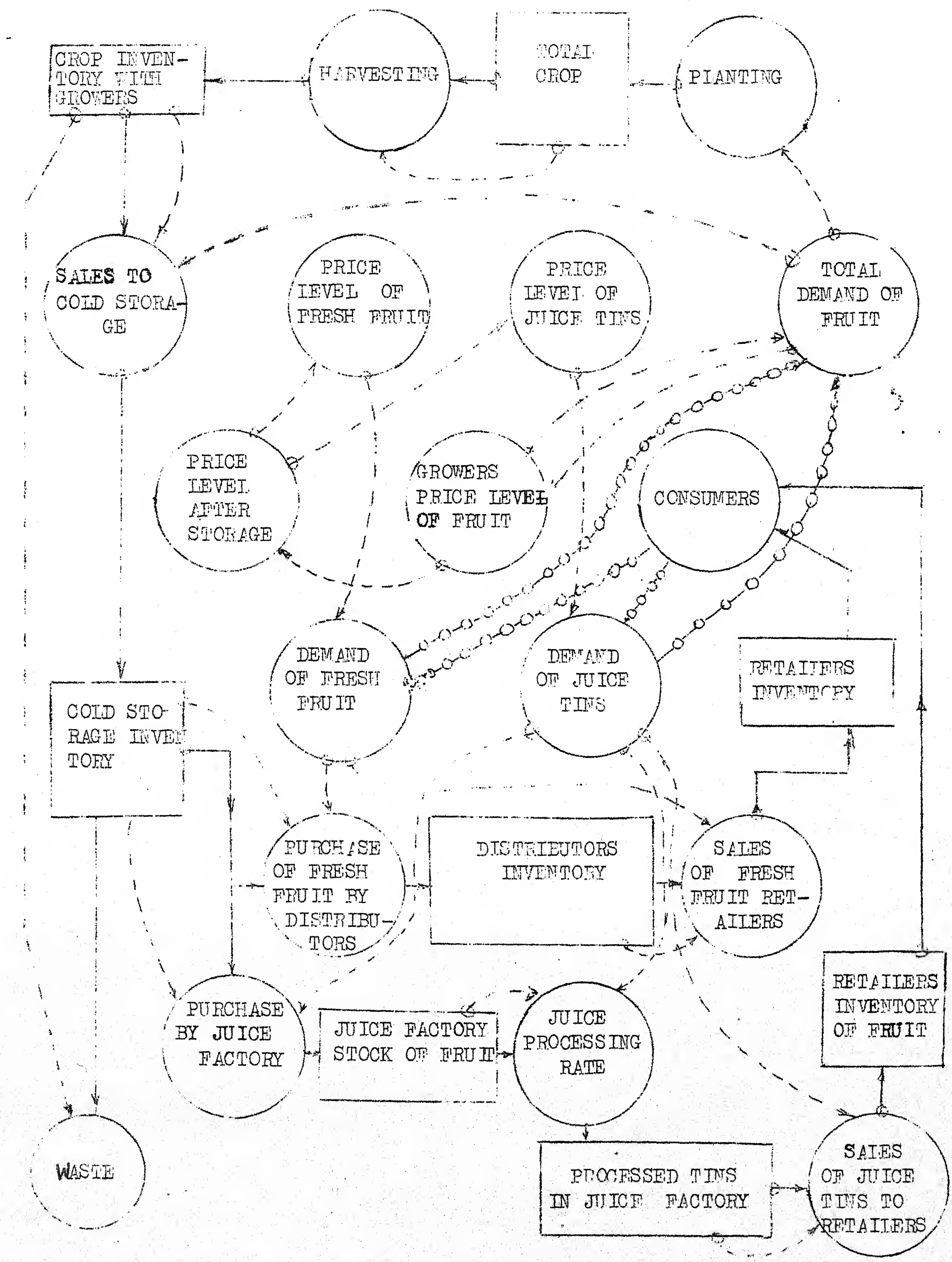


FIG.4.1 : FLOW OF MATERIAL AND INFORMATION

at agriculture etc.

Parameters – Time for fructification, fruiting period, planting period, index relating price and demand, wastage factors, inventory turnover time, etc.

(2) Cold Storage Sector :

Variables – Fruit stock in cold storage, fruit wastage, storage output rate, price level after storage, storage output back logs.

Parameters– Wastage factors, storage charges.

(3) Juice Factory Sector :

Variables – Fruit receiving rate at juice factory, demand of fruit from juice factory, demand of processed forms, processing rates, sales rates and price level etc.

Parameters – Ordering policy factor, juice content, seasonal factor, trend factor processing capacity, wastage factor, juice extraction factor, etc.

(4) Fresh Fruit Market Sector :

Variables – Fruit purchases from cold storage, weekly sales of fresh fruit to retail, retail sales rate to consumer, demand of fresh fruit etc.

Parameters– Seasonality factor, marketing charges etc.

Parameter values are either based on the available data or wherever the exact data and the information for constants and parameters are not available, suitable values have been assumed within a plausible range. Later on model sensitivity is tested for different values of parameters. To study the model sensitivity with respect to some of the important parameters, some measures of model-effectiveness are included in the model which are listed below.

4.2 <u>Measures of Model-Effectiveness</u> :

1. Total annual profit of : (a) orange growers
   (b) cold storage
   (c) juice factory
   (d) fresh fruit market, and
   (e) orange industry as a whole
2. Fluctuations of : (a) price level at growers
   (b) price level after storage
   (c) price of juice tins, and
   (d) price of oranges at fresh fruit market
3. Average values of : (a) demand/week during past year
   (b) sales/week during past year
   (c) storage output back-logs/week
   (d) wastage/week of fruit at agriculture sector.
   (e) wastage/week of fruit in cold storage

4. Dynamic stability of the system.

4.3 Selection of Programming Language for Simulation :

There are at present several methodologies for programming Industrial Dynamics simulation models, DYNAMO and FORDYN being the most popular. The first, DYNAMO, is a language developed specifically for programming Industrial Dynamics models. Equation forms and special functions of the DYNAMO are given in Appendix C. The second methodology FORDYN is not a language, but rather a simulator, developed by Llewellyn (11) for use on computer too small to accommodate the DYNAMO compiler. FORDYN employs a set of subroutines written in standard FORTRAN IV to emulate the operations of the DYNAMO compiler.

DYNAMO is used in this work as FORDYN requires many more lines of coding to program a model as compared to DYNAMO. FORDYN is a "last resort" designed for use when DYNAMO is unavailable. Llewellyn himself advocates the use of DYNAMO; "The diagnostic properties of DYNAMO, most of which could not be built into FORDYN, are so powerful that a user who has a choice should compare the two systems carefully before adapting FORDYN".

The equation number is a three fold identification number which appears in two places; in the margin beside each equation, in the text of the thesis and in the model listing (Appendix D). The equation number takes the form :

C - S - EE

where C is a one digit chapter number, S is a one digit sector

number and EE is a one or two digit equation number within the sector. For example 4-3-1 is the equation number for the Ist equation in sector 3 of Chapter 4.

4.4 Mathematical Representation of the Various Sectors :

1. Agricultural Sector - Some of the assumptions made for the agricultural sector are as follows :

1. On an average, orange trees reach fructification stage five years from planting and yield fruits for about thirty years (18)
2. The age of trees is assumed to follow a uniform distribution at the initial state.
3. Harvesting rate depends on the season and not on the demand.
4. The harvested crop is sold first to the cold storage. Demands of the processing factory or fresh fruit market is being met by the cold storage and not by the growers directly.

In order to keep track of the total crop TCROP (annual potential crop), two rates have been used. The first, rate of fructification of orange trees RFT, represents new trees just added to the total crop and the second, rate of orange trees becoming barren ROTB, represents the crop which is lost.

```
IL      TCROP.K = TCROP.J+(DT)(RFT.JK-ROTB.JK)*        4-1-1
6N      TCROP   = 900000¹
```

* The reader unfamiliar with Dynamo language is referred to the User's Manual by Pugh (16)

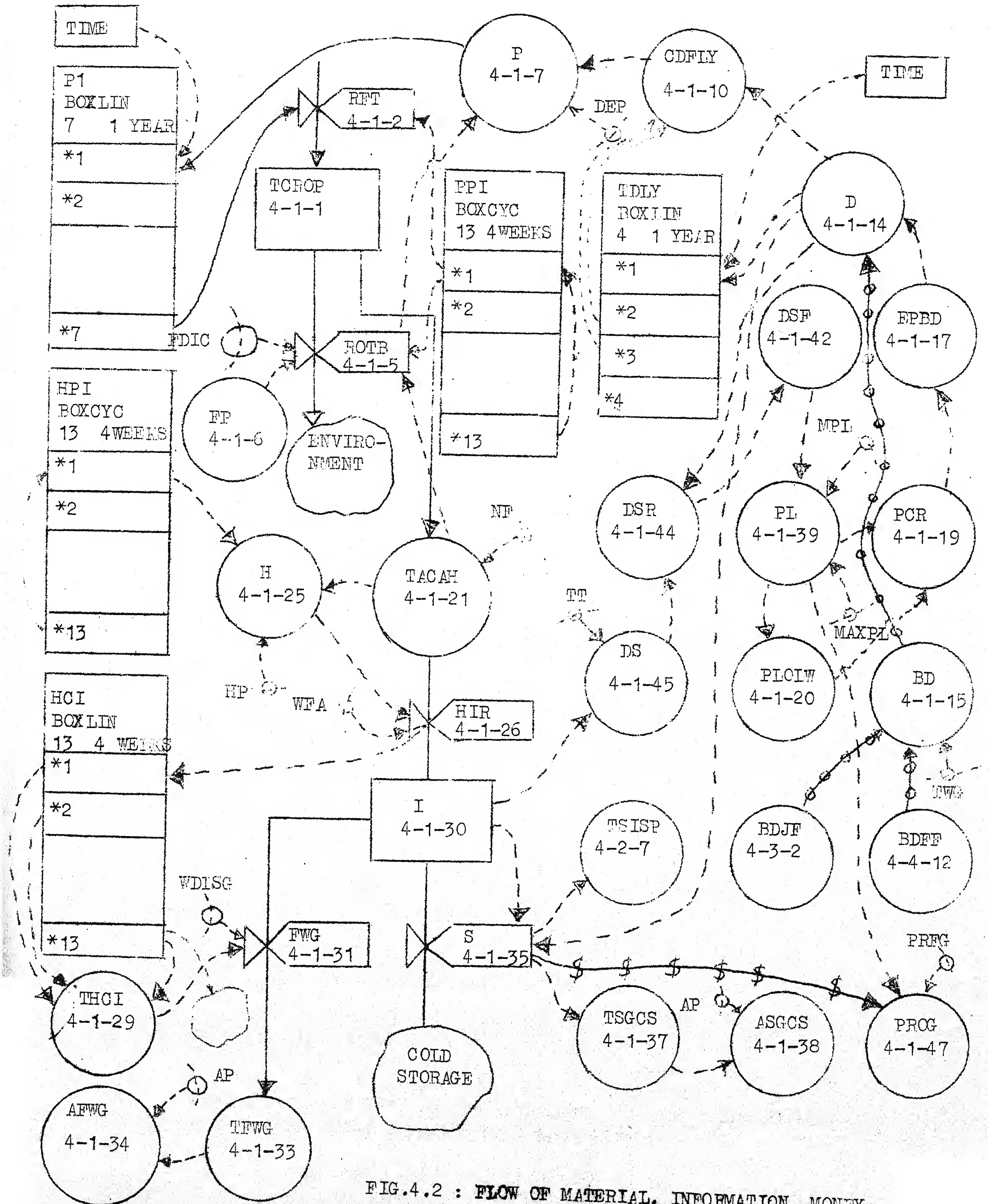


FIG.4.2 : **FLOW OF MATERIAL, INFORMATION, MONEY AND ORDERS IN AGRICULTURE SECTOR**

Rate of fructification of orange trees RFT is equal to number of orange trees planted 5 years[2] earlier divided by number of weeks FDIC during which planting was done in that year.

44R   RFT.KL = (P1*7.K)(PPI*1.K)/FDIC[3]   4-1-2

where PPI is a planting period index car-train which takes a value of 0 or 1. Value '1' corresponds to planting period and '0' to no planting. Initially, it is assumed that planting is done four times in a year, each time lasting for four weeks. Thus planting is done for 16 weeks in a year.

35B   PPI = BOXCYC(13,4)   4-1-3

C   PPI*=0/0/1/0/0/1/0/0/1/0/0/1/0

C   FDIC = 16   4-1-4

Rate of orange trees becoming barren ROTB is calculated on the assumption that an orange tree yields fruit for about FP period and at time 0, the age of the trees follows a uniform distribution (0,FP).ROTB is equal to total annual crop available for harvesting TACAH divided by the product of RDIC and fruiting period FP of an orange tree.

44R   ROTB.KL = (ROTB1.K)(PPI*1.K)/FDIC

20A   ROTB1.K = TACAH.JK/FP.K   4-1-5

---

1. Total orange production in India in 1970 is 900,000 tons(15)

2. Vide assumption 1.

3. In order to eliminate the initial value effect study of the model has to be carried for a period greater than 7 years. Thus to reduce the simulation period, P1*2 is used instead of P1*7 in order that the initial value effect is not felt after a period of 1 year itself.

The fruiting period FP of an orange tree is on an average 30 years with random fluctuations (18).

7A FP.K = 30+ FP1.K 4-1-6

33A FP1.K = (10) NOISE

The planting rate P of orange trees is such that it takes into account the number of trees that have become barren ROTB and the change in the demand from the previous year CDFLY.

6R P.KL= P3.K 4-1-7

14A P3.K=ROTB.JK + (DEP)(CDFLY.K)

where DEP is a factor determining the effect of demand on planting. For initial run a value of 0.005[1] is assumed.

C DEP = 0.005 4-1-8

To keep track of total planting done in a year, a linear boxcar train is used. The equations which calculate total planting in a year (P1*1) are :

37B P1 = BOXLIN (7,52) 4-1-9

36N P1 = BOXLOAD (30000,1)[2]

49A P1*1.K= SWITCH (30000, P 11.K, TIME.K)

7A P 11.K = AUX6.K-P12.K

41A P12.K = PULSE (AUX6.K, 53, 52)

---

1. Thus total trees planted over and above these for replacing the barren trees is equal to (52) (DEP) (CDFLY.K)

2. These are the values of total planting done during the last seven years and are based on the assumption No.2

```
7A     AUX6.K = AUX5.JK + P.JK
49R    AUX5.KL = SWITCH (0,P1*1.K, TIME.K)
6N     AUX5 = 0
```

The change in demand from last year CDFIY is calculated by using a boxcar train. The values in each of these cars are nothing but the total demand during a year TDIY. Average demand per week during the last year ADIY is calculated by dividing TDLY*1 by averaging period AP of 52 weeks.

```
7A     CDFIY.K = TDLY*2.K-TDLY*3.K                     4-1-10
37B    TDLY = BOXLIN (5,52)                            4-1-11
36N    TDLY = BOXLOAD (900000,1)
7A     TDLY*1.K = TDLY1.K - TDLY3.K
41A    TDLY3.K = PULSE (TDLY1.K, 53,52)
49A    TDLY1.K = SWITCH (900000, TDLY2.K,TIME.K)
7A     TDLY2.K= STORE.JK + D.JK
49R    STORE.KL = SWITCH (0,TDLY*1.K,TIME.K)
6N     STORE = 0
20A    ADIY.K = TDLY*1.K/AP                            4-1-12
6N     AP = 52                                         4-1-13
```

where D, the total demand per week of oranges, is calculated by incorporating EPBD, The effect of prices on the basic demand BD of oranges.

```
12R    D.KL = (BD.JK)(EPBD.K)                          4-1-14
```

where basic demand BD of oranges is given by the sum of the basic demands of the juice factory and fresh fruit market sectors

multiplied by a transportation wastage factor.

18R	BD.KL = (TWF) (BDJF.JK + BDFF.JK)	4-1-15
C	TWF = 1.2	4-1-16

EPBD, the effect of prices on the basic demand depends upon the price change ratio PCR. EPBD varies in the range of 1.5 to 0.65. The relationship between EPBD and PCR is depicted graphically in Fig.4.3 and is coded using a table function.[1]

58A	EPBD.K = TABHL(DVP, PCR.K,.5,2.5,.2)	4-1-17
C	DVP* = 1.5/1.25/1/1/.95/.9/.85/.8/.75/.7/.65	4-1-18

PCR, the price change ratio is the ratio of the price level PL in the current week and PLOLW, the price level of last week.

20A	PCR.K = PL.K/PLOLW.JK	4-1-19
6R	PLOLW.KL = PL.K	4-1-20

The harvesting rate H of the crop depends on the harvesting periods of different regions. The harvesting seasons of oranges is accounted for by using a harvesting period index HPI train which repeats the values after a cycle of one year. The harvesting rate further depends upon the total annual crop available for harvesting TACAH which is nothing but total annual crop TCROP with random fluctuations incorporated.

---

1. The graph shows that for ± 10% change in price, the demand is inelastic. Outside this range, the effect is linear. For large PCR values, the effects are constant. Furthermore demand responds to the increase in price at a faster rate than it does for decrease in the price.

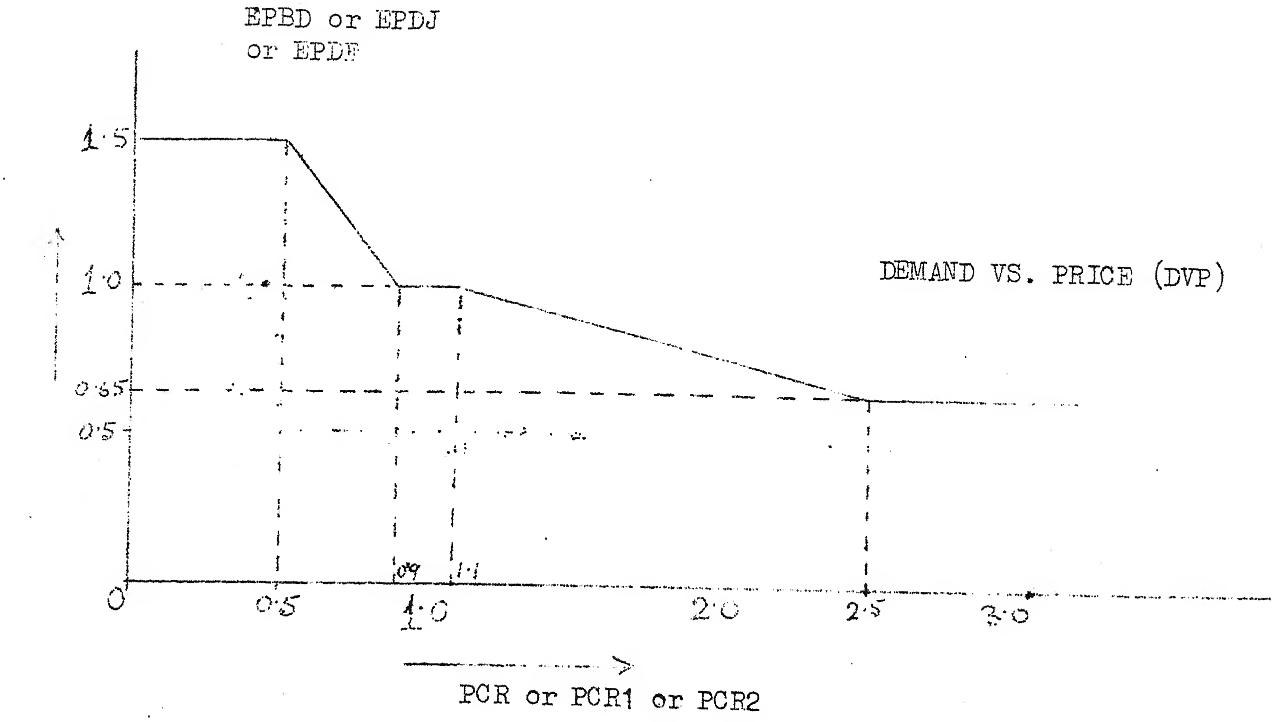


FIG.4.3 : EFFECT OF PRICES ON DEMAND

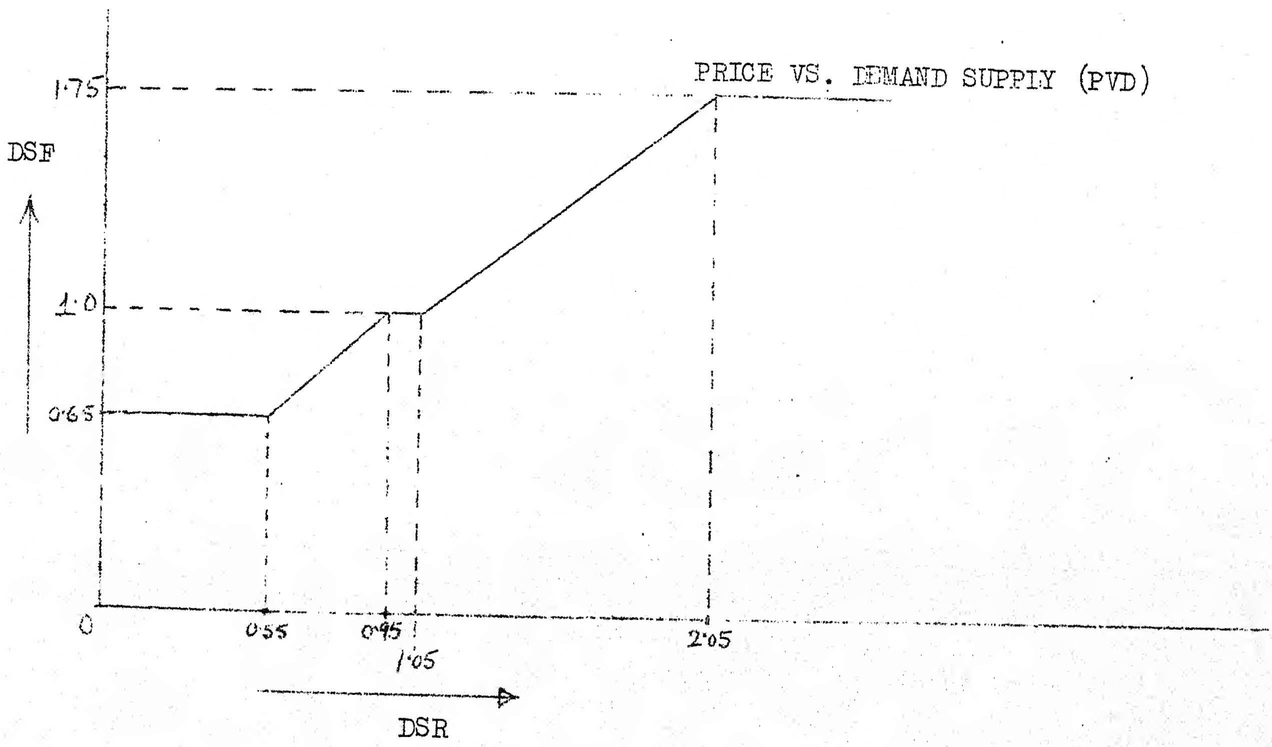


FIG.4.4 :EFFECT OF DEMAND-SUPPLY INTERACTION ON PRICES

7R	TACAH.KL = TACAH.JK + TACA2.K	4-1-21
41A	TACA2.K = PULSE (TACA1.K, 53,52)	
7A	TACA1.K = TCRP1.K-TACAH.JK	
6N	TACAH = TCROP	
18A	TCRP1.K = (TCROP.K)(1+NF.K)	
33A	NF.K = (.4) NOISE	4-1-22
35B	HPI = BOXCYC (13,HP)	4-1-23
C	HPI[1]* = .2/0/.05/.05/.05/.025/.025/0/0/.116/.117/.342/.2	
C	HP = 4	4-1-24
44A	H.K = (TACAH.JK) (HPI*1.K)/HP	4-1-25

The harvested crop goes to increase the inventory I with the farmer. The wastage during harvesting is taken into account by a factor WFA, the wastage factor at agriculture sector Since the growers cannot store the oranges with them at the field for more than 5 weeks, there is lot of wastage at agriculture sector due to longer storage (23). Thus from the crop inventory I, some fruit is wasted FWG and some is sold to the cold storage at a sale rate S.

20A	HIR.K = H.K/WFA	4-1-26
C	WFA = 1.1	4-1-27
37B	HCI = BOXL1N (6,1)	4-1-28
36N	HCI = BOXLOAD (30000 , 1)	

1 These values are based on the fact that Coorg and Nagpur are main suppliers of oranges in India and on the basis of data available about the harvesting periods at these two places.

```
6A      HCI*1.K = HIR.K
53A     THCI.K = SUM1(6,HCI.K)                        4-1-29
```

where THCI is the total harvested crop in inventory during last 5 weeks. The equations for crop inventory calculations are as follows :

```
51R     I.KL = CLIP(I2.K,I1.K, FWG1.K,0)              4-1-30
6N      I = 80000
14A     11.K = 1. JK (DT) (HS.K)
7A      HS.K = HIR.K-S.K
7A      I2.K = I1.K - FWG.K
```

The fruit wasted with growers FWG due to long storage is given by following equations :

```
56A     FWG.K = MAX(FWG1.K, 0)                        4-1-31
12A     FWG1.K = (WDLSG) (DIFF1.K)
C       WDLSG = .4                                    4-1-32
7A      DIFF1.K = I1.K - THCI.K
7R      TFWG.KL = TFWG1.K - TFWG2.K                   4-1-33
41A     TFWG2.K = PULSE (TFWG1.K, 53,52)
7A      TFWG1.K = TFWG.JK + FWG.K
6N      TFWG = 0
20S     AFWG.K = TFWG.JK/AP                           4-1-34
```

where TFWG is the cumulative fruit wasted with grower in a year and AFWG is the average fruit wastage per week.

The sales rate S to the cold storage is dependent upon the inventory at hand I and the demand rate D from the cold storage.

56A	S.K = MAX (SS1.K,0)	4-1-35
54A	SS1.K = MIN (MS.K, D.JK)	
20A	MS.K = I.JK/DT	4-1-36

where MS.K is the maximum sales rate possible.

Total cumulative sales from growers to the cold storage TSGCS during a year and average sales/week from grower to cold storage ASGCS have also been calculated.

7R	TSGCS.KL = TSGC1.K - TSGC2.K	4-1-37
41A	TSGC2.K = PULSE(TSGC1.K, 53,52)	
7A	TSGC1.K = TSGCS.JK + S.K	
6N	TSGCS = 0	
20S	ASGCS.K = TSGCS.JK/AP	4-1-38

The price level of oranges at growers varies between two limits minimum price level MPL and maximum price level MAXPL. The price level change is accounted through a demand supply interaction factor DSF.

54A	PL.K = MIN(PL2.K, MAXPL)	4-1-39
56A	PL2.K = MAX(PL1.JK, MPL)	
C	MAXPL = 5000	4-1-40
12R	PL1.KL = (PL.K) (DSF.K)	
6N	PL1 = 1000	
C	MPL = 500	4-1-41

Demand supply interaction factor DSF depends upon demand and desired sales rate DSR. The relationship between the two variables is depicted graphically in Fig.4.4 and is represented in model with following function[1],

58A	DSF.K = TABHL (PVD, DSR.K, .55, 2.05, .1)	4-1-42
C	PVD* = .65/.7375/.825/.9125/1/1/1.075/1.15/1.225/1.30/ 1.375/1.45/1.5	4-1-43
X1	25/1.6/1.675/1.75	

DSR, the demand and desired sales ratio, is given by:

20A	DSR.K = D.JK/DS.K	4-1-44

The desired sales rate is equal to a fraction of total inventory with growers

20A	DS.K = I.JK/TT	4-1-45
C	TT = 5.5	4-1-46

where TT is inventory turnover time.

The weekly profit of orange growers WPOG is obtained bpy the product of a profit margin PFTC with a weekly sales revenue. Total annual profit PROG is also calculated.

7R	PROG.KL = PROG1.K - PROG2.K	4-1-47
41A	PROG2.K = PUISE (PROG1.K, 53,52)	
7A	PROG1.K = PROG.JK + WPOG.K	
13A	WPOG.K = (PRFG)(S.K)(PL.K)	4-1-48
6N	PROG = 0	
C	PRFG = .10	

---

[1] The function is similar to that used for E.

2. <u>Cold Storage Sector</u> : The inherent assumptions made in this sector are as follows :

1. Every week, a fraction of total oranges that had been in the cold storage for a period of 12 weeks and more, goes waste (9).
2. Back logs of orders are fulfilled before new orders are met.

The amount of fruit stock in the cold storage at any moment will depend upon the storage input rate SIR, the output from the cold storage SOR and the cold storage wastage MWCS.

51R	MCST.KL = CLIP (MCST2.K, MCST1.K, MWCS1.K, 0)	4-2-1
6N	MCST = 10000	
14A	MCST1.K = MCST.JK + (DT) (SSOR.K)	
7A	SSOR.K = SIR.K - SOR2.K	
20A	SIR.K = S.K/TWF	4-2-2
7A	MCST2.K = MCST1.K - MWCS.K	

where MWCS is the material* (fruit) wasted in cold storage in a week. To calculate MWCS it is assumed that if the fruit stays in the cold storage for more than 12 weeks[1] (known as safe period - SP), a fraction WDLS of it goes as a waste.

---

* Material and fruit are used interchangeably in the text.

[1] Vide assumption 1

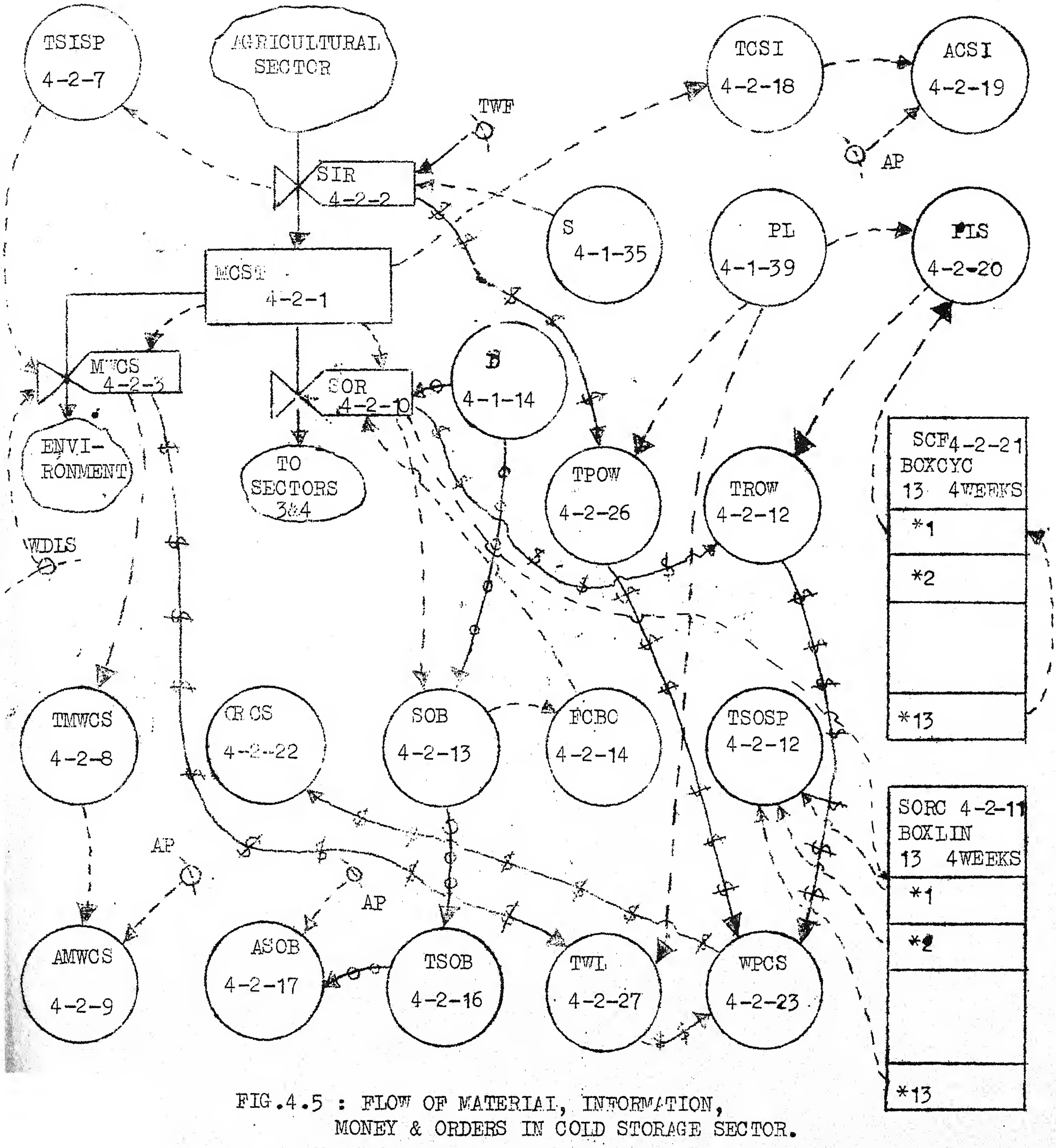


FIG.4.5 : FLOW OF MATERIAL, INFORMATION, MONEY & ORDERS IN COLD STORAGE SECTOR.

56A	MWCS.K = MAX (MWCS1.K, 0)	4-2-3
12A	MWCS1.K = (D1FF.K) (WDIS)	
7A	D1FF.K = MCST1.K - TSISP.K	4-2-4
C	WDIS = 0.2	4-2-5

where TSISP is the total storage input during the safe period SP. The storage input values for the safe period are stored in a box car and from them TS1SP is determined.

37B	SFI = BOXLIN (13,1)	4-2-6
36N	SFI = BOXLOAD (20000,1)	
6A	SFI*I.K = SIR.K	
53A	TSISP.K = SUM I(13,SFI.K)	4-2-7
C	SP = 12	

The following equations compute the cummulative (TMWCS) as well as the average (AMWCS) fruit wastage per year in cold storage :

7R	TMWCS.KL = TMWC1.K-TMWC2.K	4-2-8
6N	TMWCS = 0	
41A	TMWC2.K = PULSE (TMWC1.K, 53,52)	
7A	TMWC1.K = TMWCS.JK + MWCS.K	
20S	AMWCS.K = TMWCS.JK/AP	4-2-9

The storage output rate SOR from the cold storage is determined from the total demand of fruit D and the fruit consumed in meeting backlogs FCBO. The output rate is constrained by the availability of fruit in cold storage MCST.

6R	SOR.KL = SOR2.K	4-2-10
7A	SOR2.K = SOR1.K + FCBO.K	

54A SOR1.K = MIN(SOR3.K, D.JK)

7A SOR3.K = MCST.JK - FCBO.K

The storage output rates for past 12 weeks is stored in a box car-train SORC from which the total output during the past 12 weeks is determined.

37B SORC = BOXLIN (13,1) 4-2-11

36N SORC = BOXLOAD (16000,1)

6A SORC*1.K = SOR.JK

53A TSOSP.K = SUM1(13,SORC.K) 4-2-12

Backlogs are met as soon as material is available in the cold storage. Thus fruit consumed in backlogs FCBO is given by

9R SOB*.KL = SOB.JK + D.JK-FCBO.K-SOR1.K 4-2-13

6N SOB = 0

12A FCBO.K = (BOMI) (FCBO1.K) 4-2-14

54A FCBO1.K = MIN (MCST.JK, SOB.JK)

C BOMI = 1 4-2-15

where BOMI is the backlogs meeting index. BOMI equal to one indicates that backlogs are being met if possible. Total storage output backlogs as well as average storage output backlogs over a year are computed by the following equations :

7R TSOB.KL = TSOB1.K - TSOB2.K 4-2-16

41A TSOB2.K = PULSE (TSOB1.K, 53, 52)

7A TSOB1.K = TSOB.JK + SOB.JK

6N TSOB = 0

20S ASOB.K = TSOB.JK/AP 4-2-17

* Storage output backlog SOB in a period is given by its value in the preceding period plus increase in the backlog for not meeting the present demand less the fruit consumed in meeting backlogs FCBO.

One of the measures of model effectiveness is the average value of cold storage inventory ACSI in a year. This is calculated from the following equations :

7A	TCSI.KL = TCSI1.K - TCSI2.K	4-2-18
41A	TCSI2.K = PULSE (TCSI1.K, 53,52)	
7A	TCSI1.K = TCSI.JK + MCST.JK	
6N	TCSI = 0	
20S	ACSI.K = TCSI.K/AP	4-2-19

The price level after storage PLAS is a product of price level PL charged by growers and a storage charge factor SCF (which includes the profit of the cold storage). The SCF values are based on harvesting seasons - during the main harvesting season, SCF takes a value of 1 so that PLAS is equal to PL. This takes into account of the fact that the fruit from agricultural sector can also be sold directly to fresh fruit market or juice factory (as contrary the assumption) No. 4 made in agriculture sector.

12A	PLAS.K = (SCF*1.K) (PL.K)	4-2-20
35B	SCF = BOXCYC (13, 4)	4-2-21
C	SCF*[1] = 1/1.2/1.15/1.15/1.15/1.175/1.175/1.2/1.2/ 1.084/1.083/1/1	

The weekly profit of the cold storage WPCS is equal to the product of profit factor PF and the total receipt for the

[1] SCF values are based on HPI values.

week TROW minus total payments for the week TPOW minus total weekly losses due to the fruit wasted TWL in the cold storage because of long storage.

7R	PRCS.KL = PRCS1.K - PRCS2.K	4-2-22
41A	PRCS2.K = PULSE (PRCS1.K, 53,52)	
7A	PRCS1.K = PRCS.JK + WPCS.K	
6N	PRCS = 0	
19A	WPCS.K = (PF) (TROW.K - TPOW.K - TWL.K-0)	4-2-23
C	PF = 0.20	4-2-24

where PRCS gives the annual profit figure for the cold storage. Total receipts for the week TROW is equal to storage output rate SOR2 multipliedby the price level after storage PLAS.

12A	TROW.K = (SOR2.K) (PLAS.K)	4-2-25

Similarly, the total payments for the week (TPOW) is the product of sales input rate SIR and the price PL, charged by the growers.

12A	TPOW.K = (SIR.K) (PL.K)	4-2-26

Total weekly losses TWL is equal to the money value of the fruit wasted in a week due to long stay in cold storage.

12A	TWL.K = (MWCS.K) (PL.K)	4-2-27

3. <u>Juice Factory Sector</u> : Juice factory sector has been modelled under the following assumptions :

(1) The word 'Juice' includes all processed forms of orange like squash, jam, marmalade, jelly, etc. and 'juice factory' includes the factories rendering the above 'processing' facilities.

(2) Out of the total factory hours, some hours are spent for other fruits also.

(3) The juice content of oranges does not vary in the course of 12 weeks (called as safe period - SP) when kept in cold storages.

(4) The basic demand of the processed forms is assumed to exhibit a normal distribution. This demand of orange juice is independent of the demand of the fresh fruit market.

(5) This sector gets priority over the fresh fruit market with respect to supply of fruits.

(6) If material in stock is more than demand, the latter is met in full. Otherwise, demand is met in part.

(7) On an average 10% of the total orange production is processed every year.

Raw oranges are purchased from the cold storage, concentrated and canned in this sector before they are sold to the retail stores. Retailers sell the processed forms to the consumers.

The fruit receiving rate at juice factory sector FRRJF is computed from the total storage output rate SOR2 and the basic demand of juice factory BDJF.

6R FRRJF.KL = FRRJ1.K 4-3-1

54A FRRJ1.K = MIN (BDJF.K, SOR2.K)

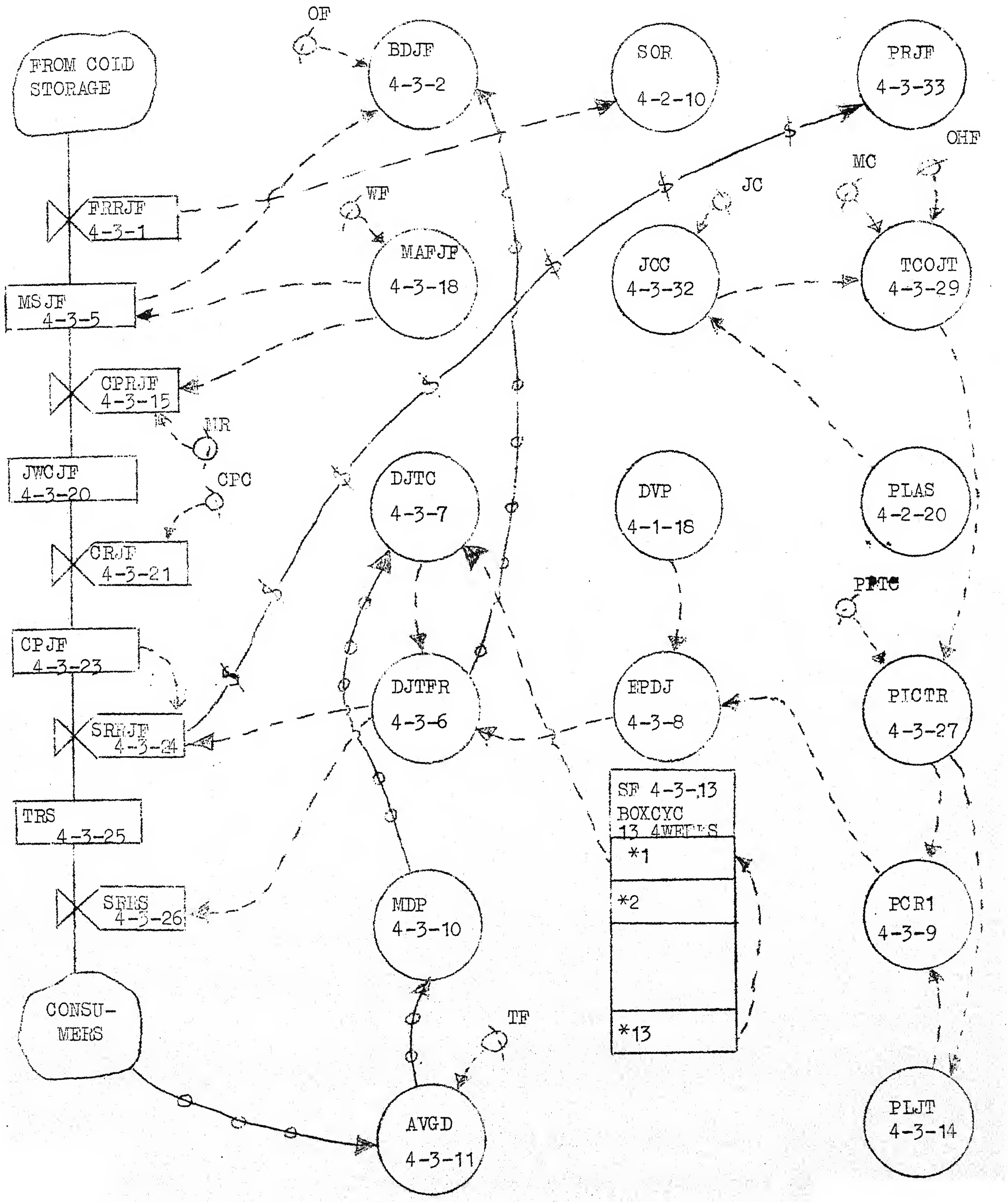


FIG.4.6 : FLOW OF MATERIAL, INFORMATION, MONEY & ORDERS IN JUICE FACTORY SECTOR

The basic demand of the juice factory BDJF is based on the difference of demand of juice tins (in terms of tons of oranges) DJTF1 and the fruit stored in the juice factory MSJF.

56A BDJF.K = MAX (AUX20.K, 0) 4-3-2

18A AUX20.K = (OF)(DJTF1.K - MSJF.K)

20A DJTF1.K = DJTFR.K/JC

where OF : an ordering factor

JC : Juice content

An ordering policy is considered where the ordering quantity is equal to twice of the difference of demand of oranges from juice factory DJTF1 sector and fruit stock in the juice factory MSJF.

C OF = 2 4-3-3

The juice content JC is assigned a value of 0.5 which is the average juice content value of oranges (9).

C JC = 0.5 4-3-4

The quantity of fruit stored in the juice factory is determined by two rates: first, by fruit receiving rate at juice factory FRRJF - an input rate; and second, by concentrate production rate at juice factory CPRJ2 - an output rate.

1L MSJF.K = MSJF.J + (DT) (FRRJF.JK - CPRJ2.K) 4-3-5

6N MSJF = 125

The demand of juice tins DJTFR is calculated from a normally distributed demand pattern MDP, a seasonality factor

SF, a trend factor TF and the effect of price changes.

56A	DJTFR.K = MAX (DJTF2.K, 0)	4-3-6
12A	DJTF2.K = (DJTC.K) (EPDJ.K)	
12A	DJTC.K = (MDP.K) (SF*1.K)	4-3-7

EPDJ is the effect of prices on the demand of juice tins. It depends upon the price change ratio PCR1 of the juice tins prices. The relationship between EPDJ and PCR1 is same as that is used for calculating the total demand of oranges (Fig.4.3).

58A	EPDJ.K = TABHL (DVP, PCR1, .5, 2.5, .2)	4-3-8
20A	PCR1.K = PLCTR.K/PLJT.JK	4-3-9

Moving demand pattern MDP is given by a normal distribution with an average value of AVGD and standard deviation of 100. The average value of AVGD is changed by a trend factor TF whereas standard deviation is assumed to be constant throughout.

34A	MDP.K = (1) NORMRN (AVGD.JK,100)	4-3-10
6R	AVGD.KL = (AVGF.JK) (TF)	4-3-11
6N	AVGD = 1000	
C	TF = 1.001	4-3-12

The seasonality factor SF accounts for seasonal change in demand. A cyclic box-car train is used to determine SF values.

35B	SF = BOXCYC (13,4)	4-3-13
C	SF* = 1.1/1./.9/.9/.7/.6/.5/.7/.9/1./1.1/1.3/1.1	

PLJT is the price of juice tins in the previous week.

6R PLJT.KL = PLCTR.K 4-3-14

The concentrate production rate CPRJF is governed by the fruit available for juice production MAFJP, the maximum rate MR (capacity) of concentrate production and the juice extraction factor JEF.

12R CPRJF.KL = (CPRJ2.K) (JC) 4-3-15

12A CPRJ2.K = (CPRJ1.K) (JEF)

54A CPRJ1.K = M1N (MAFJP.K, MR)

C JEF = 0.98 4-3-16

C MR = 1500[1] 4-3-17

The fruit available for juice production MAFJP is computed from fruit stored in juice factory MSJF multiplied by a wastage factor WF.

12A MAFJP.K = (WF) (MSJF.K) 4-3-18

C WF = 0.9 4-3-19

The concentrate produced is then canned. Thus the juice waiting for canning at juice factory JWCJF is given by :

1L JWCJF.K = JWCJF.J +(DT) (CPRJF.JK - CRJF.JK)4-3-20

6N JWC JF = 75

The canning rate at the juice factory CRJF is based on JWCJF and the canning production capacity CPC.

54R CRJF.KL = M1N (CPC, JWCJF.K) 4-3-21

C CPC = 1500[2] 4-3-22

1&2 These figures are based on the assumption that present processing capacities are sufficient to process 10% of the total orange production in a year(vide assumption No.7).

The level of canned tins in juice factory depends upon the canning rate CRJF and the sales rate to retail from juice factory SRRJF.

1L CTJF.K = CTJF.J + (DT) (CRJF.JK - SRRJF.JK) 4-3-23

6N CTJF = 5000

The sales rate to retail from juice factory SRRJF is the minimum of DJTFR and the CTJF.

54R SRRJF.KL = MIN (DJTFR.K, CTJF.K) 4-3-24

These tins are stored in the retail stores before they are sold to the consumers for consumption. The retailer stock of juice tins is given by tins in retail stores TRS.

1L TRS.K = TRS.J + (DT) (SRRJF.JK - SRRS.JK) 4-3-25
6N TRS = 1000

where SRRS is the sales rate from retail stores to the consumers. The calculation of SRRS is similar to that of SRRJF. It depends upon the tins in retail store TRS and the demand of juice tins DJTFR.

54R SRRS.KL = MIN (TRS.K, DJTFR.K) 4-3-26

The price level of canned tins PLCTR is based on the total cost of juice tins TCOJT and a profit factor PFTC over total cost TCOJT.

12A PLCTR.K = (PFTC) (TCOJT.K) 4-3-27

C PFTC = 1.30 4-3-28

The total cost of juice tins consists of juice content cost JCC, manufacturing cost MC and the overhead cost factor OHF.

18A	TCOJT.K = (OHF) (MC + JCC.K)	4-3-29
C	MC = 1000	4-3-30
C	OHF = 2	4-3-31

The juice content cost JCC is the price of oranges charged to the juice factory by the cold storage divided by the juice content of oranges JC

20A	JCC.K = PLAS.K/JC	4-3-32

The profit of the juice factory is equal to the difference of the sales value and the total cost. Profit figure over a year is calculated as one of measures of model effectiveness.

7R	PRJF.KL = PRJF1.K - PRJF2.K	4-3-33
41A	PRJF2.K = PULSE (PRJF1.K, 53, 52)	
6N	PRJF = 0	
14A	PRJF1.K = PRJF.JK + (DT) (AUX 7.K)	
13A	AUX7.K = (.30) (TCOJT.K) (SRRJF.JK)	

4. <u>Fresh Fruit Market Sector</u> : The assumptions made in modeling this sector are listed below :

1. The fruit for direct sale is obtained only from the cold storage.
2. The demand for the fresh fruit follows a normal distribution.

The fruit distributors purchase fruit from the cold storage and sell it to the retailers. The retailers further sell the oranges to the consumers. The fruit purchase

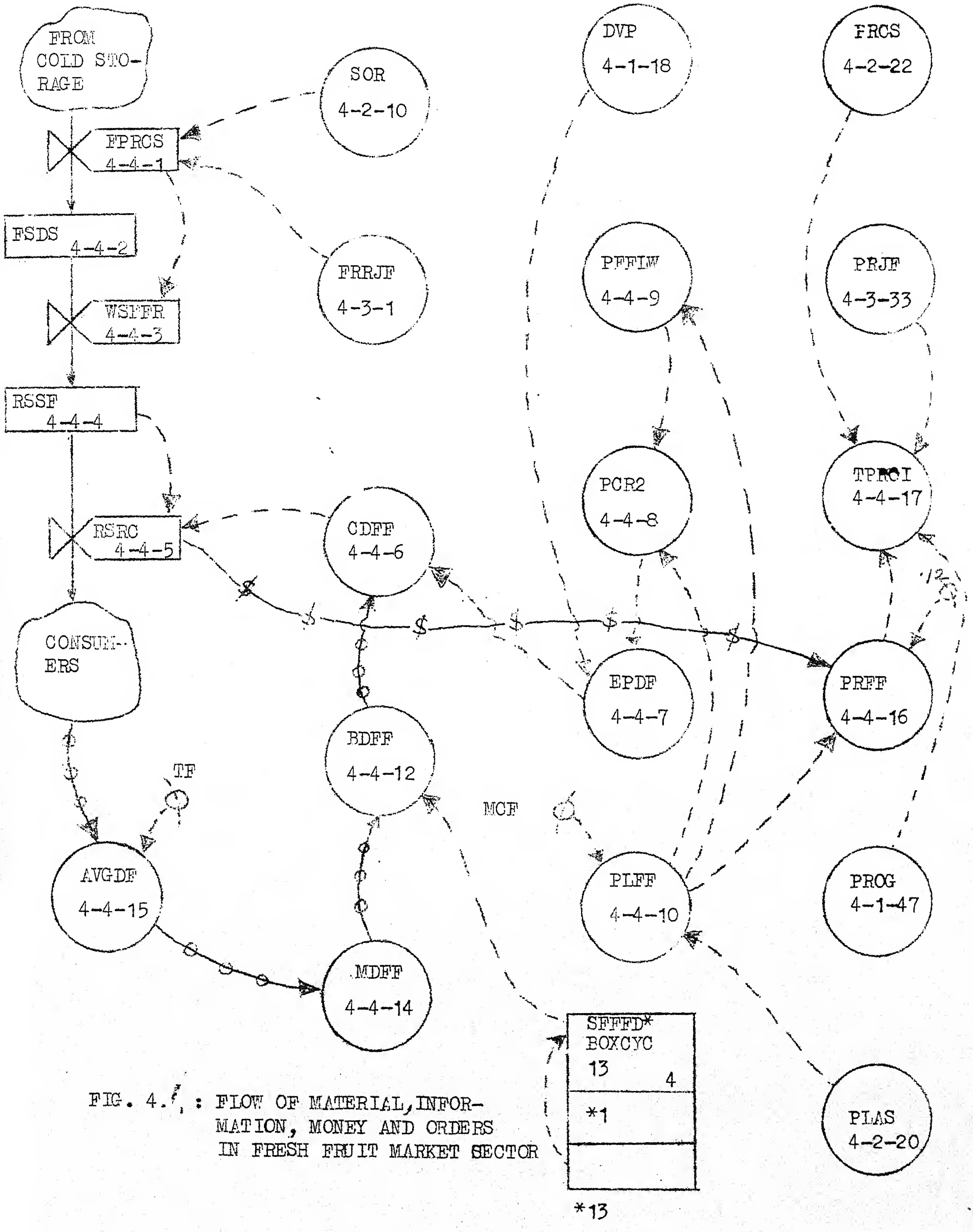


FIG. 4.?: FLOW OF MATERIAL, INFORMATION, MONEY AND ORDERS IN FRESH FRUIT MARKET SECTOR

rate from the cold storage is equal to the storage output rate SOR minus the fruit received by the juice factory FRRJ1.

7R FPRCS.KL = SOR2.K - FRRJ1.K 4-4-1

This forms a fruit stock for direct sale FSDS with the distributors from where weekly sales of fresh fruit to retail stores are made.

1L FSDS.K = FSDS.J + (DT) (FPRCS.JK - WSFFR.JK) 4-4-2

6N FSDS = 14000

The weekly sale of fresh fruit to retail is equal to fresh fruit purchase rate from the cold storage delayed by one week.

6R WSFFR.KL = FPRCS.JK 4-4-3

The retail store stock of fresh fruit RSSF is dependant upon the input rate WSFFR and the output rate RSRC.

1L RSSF.K = RSSF.J + (DT) (WSFFR.JK - RSRC.JK) 4-4-4

6N RSSF = 1000

where RSRC is the retail sales rate to consumer. It depends on the consumer demand of fresh fruit CDFF and the retail shop stock of fresh fruit RSSF

54R RSRC.KL = MIN (CDFF.K, RSSF.K) 4-4-5

The consumer demand of fresh fruit CDFF comprises of the basic demand of fresh fruit BDFF and the price change effect on this demand EPDF.

56A CDFF.K = MAX (CDFF1.K, 0) 4-4-6

12A CDFF1.K = (BDFF.K) (EPDF.K)

The relationship between the effect of price on the demand of fresh fruit is given by the Fig.4.3and is included here with the help of a table function.

58A EPDF.K = TABHL (DVP, PCR2.K, .5, 2.5, .2) 4-4-7

20A PCR2.K = PLFF.K/PFFLW.JK 4-4-8

where PCR2 is equal to the ratio of price of fresh fruit in the current week and the price of fresh fruit in the last week. PLFF is equal to the product of the price level after storage PLAS and the marketing charges factor MCF.

6R PFFLW.KL = PLFF.K 4-4-9

12A PLFF.K = (MCF) (PLAS.K) 4-4-10

C MCF = 1.15 4-4-11

The basic demand of fresh fruit comprises of the moving demand of fresh fruit MDFF and a seasonal factor for fresh fruit SFFFD.

12R BDFF.KL = (MDFF.K) (SFFFD*1.K) 4-4-12

35B SFFFD = BOXCYC (13,4) 4-4-13

C SFFFD* = .9/.7/.7/.7/.7/.9/1./1.1/1.2/1.3/1.5/1.4/1.

The moving demand of fresh fruit MDFF is assumed to exhibit a normal distribution with a variable average value AVGDF and a standard deviation of 1000.

34A MDFF.K = (1) NORMRN (AVGDF.JK, 1000) 4-4-14

AVGDF isthe average demand of fresh fruit having a trend incorporated in it.

12R AVGDF.KL = (AVGDF.JK) (TF) 4-4-15

6N AVGDF = 15000

CHAPTER V

RESULTS AND DISCUSSIONS

This Chapter deals with system simulation results. Interpretation and explanations follow the discussion of results. Recommendations for further work are given at the end of this Chapter.

A study of the behavior of a system involves investigations pertaining to the effect of changes in the variables and parameters with respect to time. Thus an outline of the behavior of the variables is presented in this Chapter. The exogenous variables e.g. demand, planting and harvesting periods etc. incorporate seasonality to account for the seasonal nature of oranges. As one would expect this seasonality in exogenous variables gets reflected into endogeneous variables. This claim is justified by the nature of the various graphs shown in figures 1 to 48 (Appendix C).

5.1 SYSTEM BEHAVIOR

There are four pertinent variables in any production-inventory system - Demand, Sales, Inventory and Price-levels.

In the present study demand is an exogenous variable. Demand is characterised by an upward trend with a 'super-imposed' seasonal factor. Further random noise is imposed on the demand which is also affected by fluctuations in prices. The total

demand of oranges is a sum total of the demands from juice factory sector (BDJF) and fresh fruit market (BDFF). Figures 2,4&5 depicts the total demand and the demand of sectors (3) and (4).

Inventory adjusts itself to demand and consequently the seasonal pattern of inventory (Fig. 2). Inventory reaches a zero value during some periods when harvesting is nil. The various inventories (i.e. Crop inventory I, Cold storage inventory MCST, juice factory inventory of fruits (MSJF) and fresh fruit market inventory (FSDS))are shown in figures 2 to 5.

Further the seasonality effect present in demand and available inventory gets reflected in the sales rate at various levels are shown in figures 2 to 6.

Price level (PL) depends on demand (D) and supply I i.e. an exogeneous variable D and an endogeneous variable I. It is allowed to vary between plausible maximum and minimum limits. Within these limits PL shows a cyclic nature as expected. The variations in the four price levels - Price level after storage (PLAS), Price level of canned tins (PLCTR) and Price level of fresh fruit (PLFF) incorporated in the model, are shown in figure 1.

To summarise, the pertinent variables described above behave more or less as expected, without sudden breaks, jumps etc. testifying to the validity of the model.

Furthermore an examination of figures 2&3 reveals that the system is not able to meet demand in full from the cold storage and therefore the backlogs (ASOB). These backlogs are increasing continuously. This situation can be explained by the fact that the total demands outruns supply. The only remedy is to increase the supply of oranges.

Planting rate has been modelled to follow demand (D) and number of trees becoming barren (BOTB). The variation in planting rate shows a cyclic nature with a period of 13 weeks (Fig.2).

Harvesting rate also portrays a cyclic nature showing that harvesting is done in only certain periods of the year. This is also dependent on the effect of weather conditions (a noise) on total annual crop available for harvesting (TACAH).

Wastage at the cold storage is very little as compared to the wastage with the growers. Large wastage with growers is due to the fact that harvesting of crop is concentrated in a period whereas demand is comparatively distributed over the year. Therefore large amount of fruit is carried over for more than 5 weeks - the safe storage period at the field. On the other hand in cold storage where fruit can stay in good condition without deterioration in quality for 12 weeks, negligible quantity of fruit is carried over beyond a period of 12 weeks.

5.2 MODEL SENSITIVITY TO THE PARAMETERS

System behavior due to variation in four parameters is studied. Parameter values used in the initial run and in subsequent simulation runs are given below.

ulation run	Inventory turn-over time TT	Wastage factors WDIS& WDISG	Backlog meeting index BOMI	Demand effect on planting DEP	Trend factor TF
Initial run	5.5	0.2 and 0.4	1	0.005	1.001
Variation in TT	5.0	0.2 and 0.4	1	0.005	1.001
Variation in TT	6.0	0.2 and 0.4	1	0.005	1.001
No wastage	5.5	0.0 and 0.0	1	0.005	1.001
Backlogs are not met	5.5	0.2 and 0.4	0	0.005	1.001
Demand does not effect planting	5.5	0.2 and 0.4	1	0	1.001
No trend in demand	5.5	0.2 and 0.4	1	0.005	1
*Step input to demand having no trend	5.5	0.2 and 0.4	1	0.005	1

n this run a step input to demand is given. Further it should be oted that there is no trend in the demand.

The systems behavior corresponding to the initial simulation run has been described in the previous section.

The effect on systems behavior due to variation in four parameters is discussed below. A comparison of system behaviors is made between the initial simulation run and subsequent simulation runs.

Variation in the Value of Inventory Turn-over time TT
(Simulation run No. 2 and 3)

With increase in TT the price changes very rapidly. A study of figures 7 to 18 reveal that in the 120th week, for values of TT equal to 5 weeks and 6 weeks the price level per week increases by Rs. 300/- to Rs. 700/- respectively. Similarly for values of TT equal to 5 weeks and 6 weeks the 104th week shows price level per week decreasing by Rs.525/- and Rs.300/- respectively. This is explained by the fact that as TT increases the desired sales rate (DS) decreases. This increases the factor DSF and as a consequence of which price changes rapidly with time. Profit however shows a decline with increasing values of TT (Table 5.1) other variables including inventory remain unaffected by changes in TT within the selected range.

TABLE 5.1

EFFECT OF INCREASE OF TT* ON PROFITS

(Profit values are in x 10^3 Rs/year)

TT (Weeks) / Year	TPROI 5	TPROI 5.5	TPROI 6	PROG 5	PROG 5.5	PROG 6	PRCS 5	PRCS 5.5	PRCS 6
1	488.23	504.08	523.37	146.92	150.40	153.94	22.33	27.05	31.235
2	568.16	589.28	628.03	180.71	182.91	190.63	23.31	25.39	29.846
3	551.91	578.98	620.78	168.26	178.40	191.73	26.539	31.250	35.118

TABLE 5.1 (CONTD.)

TT (Weeks) / Year	PRJF 5	PRJF 5.5	PRJF 6	PRFF 5	PRFF 5.5	PRFF 6
1	122.32	124.48	130.08	203.13	209.14	215.14
2	120.65	127.24	131.68	249.92	259.79	273.87
3	130.93	133.39	138.04	235.27	245.04	265.00

* Inventory Turnover Time

TABLE 5.2

CASE OF NO WASTAGES

(All values are in x 10^3 Tons/Week)

Year	ACSI		TSGCS		ASOB		TPROI	
	WDLS=.2 WDLSG=.4	WDLS=0 WDLSG=0	WDLS =.2 WDLSG=.4	WDLS = 0 WDLSG= 0	WDLS =.2 WDLSG=.4	WDLS = 0 WDLSG= 0	WDLS =.2 WDLSG=.4	WDLS =0 WDLSG=0
1	12.183	15.182	785.48	973.6	175.3	110.83	504.08	467.80
2	13.068	16.241	830.20	1028.3	411.4	200.02	589.28	548.83
3	11.69	12.998	748.75	830.8	446.0	320.0	578.98	552.49

TABLE 5.2 (CONTD.)

Year	PROG		PRJF		PREF		PRCS	
	WDIS =.2 WDLSG=.4	WDLS=0 WDISG=0	WDIS =.2 WDISG=.4	WDLS =0 WDISG=0	WDIS =.2 WDISG=.4	WDIS =0 WDISG=0	WDIS =.2 WDISG=.4	WDIS =0 WDISG=0
1	150.40	144.31	124.48	102.08	209.14	207.67	27.057	23.929
2	182.91	182.20	127.24	103.83	259.79	248.29	25.393	30.751
3	178.40	174.05	133.39	127.40	245.04	238.59	31.250	21.416

TABLE 5.3

CASE OF LOST SALES

Year	ACSI x 10^3 Tons/Week		TPROI x 10^6 Rs/Year		PROG x 10^6 Rs/Year	
	BOMI=1	BOMI=0	BOMI=1	BOMI=0	BOMI=1	BOMI=0
1	12.183	12.444	504.08	505.34	150.40	150.40
2	13.06	13.214	589.28	589.29	182.91	182.91
3	11.69	12.342	578.98	581.74	178.40	178.40

TABLE 5.3 (CONTD)

Year	PRCS x 10^6 Rs/Year		PRJF x 10^6 Rs/Year		PRFF x 10^6 Rs/Year	
	BOMI=1	BOMI=0	BOMI=1	BOMI=0	BOMI=1	BOMI=0
1	27.057	27.090	124.48	124.48	209.14	210.366
2	25.393	25.403	127.24	127.24	259.79	259.79
3	31.250	30.702	133.39	133.39	245.04	248.34

TABLE 5.4(a)

EFFECT OF TF* AND STEP INPUT ON SYSTEM VARIABLES

(All values are in x 10^3 Tons/Week)

Δ = Sudden change in average demand

Year	TDIY			TSGCS			ASGCS		
	TF= 1.001	TF= 1.00	TF= 1.00 with Δ	TF= 1.001	TF= 1.00	TF= 1.00 with Δ	TF= 1.001	TF= 1.00	TF=1 with Δ
1	1052.3	1029.3	1029.3	786.48	779.19	779.19	14.713	14.594	14.594
2	1109.1	1031.5	1107.2	830.20	791.27	833.99	15.531	14.826	15.606
3	1154.2	1019.8	1093.2	748.75	706.72	731.40	13.931	13.191	13.625

TABLE 5.4(a) (CONTD.)

Year	ACSI			TFWG			ASOB		
	TF= 1.001	TF= 1.00	TF=1 with Δ	TF= 1.001	TF= 1.00	TF=1 with Δ	TF= 1.001	TF= 1.00	TF=1 with Δ
1	12.133	12.099	12.099	186.92	190.78	190.78	175.3	170.16	170.16
2	13.068	12.495	13.107	197.41	234.06	200.99	411.4	383.43	398.84
3	11.690	11.084	11.449	79.89	124.00	90.88	446.0	377.0	421.89

* Trend Factor

TABLE 5.4(b)

EFFECT OF TF AND STEP INPUT ON SYSTEM VARIABLES (PROFITS)

(All values are in x 10^6 Rs / Year)

Δ =Sudden change in average demand

Year	TPROI			PROG			PRCS		
	TF= 1.001	TF= 1.00	TF=1.0 with Δ	TF= 1.001	TF= 1.00	TF=1.0 with Δ	TF= 1.001	TF= 1.00	TF=1.0 with Δ
1	504.08	502.40	502.40	150.40	148.03	148.03	27.057	26.88	26.88
2	589.28	558.14	587.16	182.91	172.83	181.60	25.393	24.687	24.994
3	578.98	514.58	568.68	178.40	155.96	169.31	31.250	27.690	30.774

TABLE 5.4(b)(CONTD.)

Year	PRJF			PRFF		
	TF=1.001	TF=1.00	TF=1.0 with Δ	TF=1.001	TF=1.00	TF=1.0 with Δ
1	124.48	127.53	127.53	209.14	206.59	206.59
2	127.24	121.49	131.14	259.79	244.39	255.45
3	133.39	123.58	142.67	245.04	215.02	234.65

No. Wastage (Simulation run No.4)

It is assumed that there is no wastage at the growers or in the cold storage. This results in an increase in the cold storage inventory (ACSI) and the total sales from growers (TSGCS) as shown in Table 5.2. However, with increased inventory at all stages price levels go down considerably. Thus although sale is more the effect of decrease in price is more predominant and the total profit shows a decline. The fluctuations of various inventory levels (I, MCST, MSJF etc.) are shown in Figures 19 to 24.

Back logs are not met (Simulation run No.5)

This is a case of lost sales (Figs. 25 to 30). The inventory at cold storage increases but not appreciably. Total profit shows a small increase attributable to the fresh fruit market. Since the variation in profit at various sectors is either zero or negligible the overall profit shows negligible increase in its value (Table 5.3).

Demand does not affect planting rate (Simulation run No.6)

The only change observed in the results is that the planting rate has decreased (Figures 31 to 36). The new planting rate replaces the trees that have become just barren and is not affected by demand. The effect on other variables such as total annual crop (TACAH), harvesting rate (H), and inventories is indicated in the results. This is due to the fact that simulation

was carried for the period of 3 years only, whereas planting affects these variables after a period of 5 years approximately.

No trend in demands (Simulation run No.6)

The results of this simulation run are described in Tables 5.4 and 5.5. Due to decrease in demand the total annual sales have decreased significantly resulting in high wastage with growers. Growers inventory I shows an increase while the cold storage inventory MCST shows a decline. Average storage output backlogs ASOB decreases due to lower demand (Figures 37 to 42).

Step input to demand with no trend (Simulation run No.7)

The demand is given a step increase at the end of one year. Throughout the run it is assumed that there is no trend. Comparing the results of this run with run No.6 one finds that the total annual sales from growers (TSGCS) have increased (Table 5.4). Fruit wastage at growers has decreased significantly due to increase in demand. The behavior of important variables due to a step input to demand are shown in Figures 39 to 48. The total profit is increased due to increase in the profit at all sectors (Table 5.5).

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

The purpose of the work, as described in Chapter I, was two-fold. First, an attempt was made to develop a model describing the systems behavior of a perishable commodity industry and for this an Industrial Dynamics methodology was made use of. The other purpose of the work was to make a sensitivity analysis with respect to the parameters of the system. Results indicate that the model variables expose a behavior, in keeping with the expectations - testifying to the validity of the model. The system is found to be sensitive to inventory turnover time (TT) but is insensitive to the factor (DEP) representing effect of demand on planting. Increased demand gives better system performance in terms of higher profits and low wastages. However, the increase in back orders increases customer dis-satisfaction. System performance is not much improved by allowing for lost sales. Greater customer satisfaction results with a reduction in wastages, which, however, does not necessarily imply increased profits, as the price level drops with increasing inventories.

The formulation, validation and subsequent improvements of a large complex system is an onerous and a lengthy undertaking. However, one of the attractive features of simulation is that the flexibility allowed in the construction of the simulation model

permits a corresponding flexibility in the use of the model. The model proposed for the system of an orange industry can be used for any other fruit as well displaying similar characteristics.

The same model can be utilised to study the behavior of a non-perishable commodity also, as was done in the case of the run with no wastages. The model can further be used to gain insight into the areas of policy reformulation or for altering structure in order to improve performance.

There are several avenues for the extension of the presented work. One of such avenues may be to make an attempt to relax some of the assumptions of the above model. For example, distribution and transportational details can be added in order to improve upon usefulness of the proposed model. Incorporation of intangible variables like - quality deterioration, customer satisfaction and possible technological breakthroughs would yield a more realistic picture of the system.

REFERENCES

1. Ansoff, H.I. and D.P. Slevin, "An Appreciation of Industrial Dynamics", Management Science, Vol. 14, No. 7 (March 1968), pp. 68-73.
2. Ansoff, H.I. and D.P. Slevin, "Comments on Professor Forrester's 'Industrial Dynamics - After the First decade," Management Science, Vol. 14, No. 9 (May 1968), p.600.
3. Butler, J.K., The Design of an Adaptive Control System for Management of a Storage and Marketing Facility", Ph.D. Thesis, Arizona State University, 1971.
4. Forrester, J.W., Industrial Dynamics, M.I.T. Press, Cambridge, Massachusetts, 1961.
5. Forrester, J.W., "Industrial Dynamics - After the First Decade", Management Science, Vol. 14, No.7 (March 1968), pp. 398-415.
6. Forrester, J.W., "Industrial Dynamics - A. Response to Ansoff and Slevin," Management Science, Vol. 14, No.9 (May 1968), pp. 601-618.
7. Forrester, J.W., "Managerial Decision Making", from Management and the Computer of the Future, M. Greenberger (Ed.), The M.I.T. Press, Cambridge, Massachusetts, 1962, pp.36-68.
8. Jarmain, E.W., Problems in Industrial Dynamics, The M.I.T. Press, Cambridge, Massachusetts, 1963.

16. Pugh Alexander, L., III, DYNAMO User's Mannual, 2nd Edition, The M.I.T. Press, Cambridge, Massachusetts, 1964.

17. Randhawa, G.S. and A.S. Kahlan, "Effect of Marketing Technology on Citrus Industries in India", I.A.R.I. Publication, New Delhi, 1947-59.

18. Ranjit Singh, Fruits, National Book Trust of India, New Delhi.

19. Roberts, E.B., Dan I. Abrams and H.B. Weil, "A Systems Study of Policy Formulation in a Vertically integrated Firm", Management Science, Vol. 14, No. 12 (Aug. 1968), pp. B-674-to B-694.

20. Roberts, E.B., "Industrial Dynamics and the Design of Management Control Systems", Management Technology, Vol. 3, No. 2 (December 1963), pp. 100-118.

21. Roberts, E.B., The Dynamics of Research and Development, Harper and Row, New York, 1964.

22. Schrank, W.E. and C.C. Holt, "Critique of Verification of Computer Simulation Models", Management Science, Vol. 14, No.2 (October 1967), pp. B-104 to B-106.

23. Sham Singh, S. Krishnamurthi and S.L. Katyal, "Fruits Culture in India", Published by I.C.A.R., New Delhi, Chap.13, 1963.

24. The Wealth of India : Raw Materials, Vol. II, C.S.I.R., Delhi, 1950, pp. 193-205.

9. Kripal Singh, K., Storage Behaviour of Sweet Oranges and Mandarins, I.C.A.R. Technical Bulletin (Agric. Series), No. 35, 1971.

10. Llewellyn, R.W., "Computer Programming for Industrial Dynamics", special lecture delivered at Purdue University, 1969.

11. Llewellyn, R.W., FORDYN : An Industrial Dynamics Simulator, Typing Service (Privately Printed), Raleigh, North Carolina, 1965.

12. Millen, R.N. and Colin, L. Moodie, Some Effects of Computer Process Control on Management Informations and Control, Report Number 31, Purdue Laboratory for Applied Industrial Control, Schools of Engineering, Purdue Lafayette, Indiana, August 1970.

13. Naylor, T.H. and J.M. Finger, "Verification of Computer Simulation Models", Management Science, Vol. 14, No. 2 (Oct. 1967), pp. B-92 to B-101.

14. Prato Anothony Alfred, "An Econometric Study of Consumer Demands for fresh Oranges and Frozen Concentrated Orange Juice", Ph.D. Thesis, University of California, Berkeley, 1969.

15. Production Year Book, Annuaire De La Production, Annario De Production Food and Agriculture Organisation of the U.N., Rome, Vol. 24, 1970.

16. Pugh Alexander, L., III, DYNAMO User's Mannual, 2nd Edition, The M.I.T. Press, Cambridge, Massachusetts, 1964.

17. Randhawa, G.S. and A.S. Kahlan, "Effect of Marketing Technology on Citrus Industries in India", I.A.R.I. Publication, New Delhi, 1947-59.

18. Ranjit Singh, Fruits, National Book Trust of India, New Delhi.

19. Roberts, E.B., Dan I. Abrams and H.B. Weil, "A Systems Study of Policy Formulation in a Vertically integrated Firm", Management Science, Vol. 14, No. 12 (Aug. 1968), pp. B-674- to B-694.

20. Roberts, E.B., "Industrial Dynamics and the Design of Management Control Systems", Management Technology, Vol. 3, No. 2 (December 1963), pp. 100-118.

21. Roberts, E.B., The Dynamics of Research and Development, Harper and Row, New York, 1964.

22. Schrank, W.E. and C.C. Holt, "Critique of Verification of Computer Simulation Models", Management Science, Vol. 14, No.2 (October 1967), pp. B-104 to B-106.

23. Sham Singh, S. Krishnamurthi and S.L. Katyal, "Fruits Culture in India", Published by I.C.A.R., New Delhi, Chap.13, 1963.

24. The Wealth of India : Raw Materials, Vol. II, C.S.I.R., Delhi, 1950, pp. 193-205.

GENERAL REFERENCES

Ackoff, R.L., 'Management Mis-information Systems', Management Science, Vol. 14, No. 4, (Dec. 1967), pp B-147-156.

Bhatnagar, H.C., 'Development of Mandarin Orange Processing Industry', Indian Food Packer, 21 (5), pp 11-15, 1967.

Bonini, C.P., R.K. Facdicke, and H.M. Wagner, Management Controls: New Directions in Basic Research, Mcgraw-Hill Book Company, New York, 1964.

Carlson, B.R., 'An Industrialist Views I.D.', Ind. Mgt. Review, Sloan School, M.I.T., Vol. 6, No. 1 (Fall 1964) pp 15-20.

Carlson, B.R., 'Industrial Dynamics', Management Science, May-June 1964, pp 32-39.

Cheema, G.S., Karmarkar, D.V., & Joshi, B.M., Cold Storage of Nagpore Oranges, Indian Jr. Agric. Sci. 7:168 1937.

Chen, S.H., Storage of Citrus Fruits, Bull. Coll. Agric. Univ. Nanking, 28. (Hort. Abstr. Dec. 1935). 1934

Forrester, J.W., 'Common Foundations Underlying Engg. & Mgt.', Spectrum Institute of Electrical & Electronic Engrs., Vol. 1, No. 9, Sept. 1964, pp 66-77.

Forrester, J.W., 'Modeling of Market & Component Inter-actions', Marketing & Economic Development, Proc. of 1965 fall, Conf. 1965 pp 353-364.

Forrester, J.W., 'The Structure Underlying Management Process', Proc. of the 24th Annual Meeting, Academy of Management, Dec. 1964, pp 58-68.

Forrester, J.W., 'Structure and Dynamics of Feed-back Systems in Marketing', Industrial Management Review, Sloan School, M.I.T., Vol. 9, No. 2, 1967.

Goetz, B.E., 'Synthesis of Different Management Analysis Techniques', Management Science, 15, No. 10, (June 1969) pp B-506-11.

Hayes, W.B., Fruit Growing in India, Kitabistan, Allahabad 1953.

Horn, R.L., Van, 'Validation of Simulation Results', Management Science, Vol. 17, No. 5, (Jan. 1971) pp 247-58.

Karmarkar, D.V. and Joshi B.M., 'Investigations on the Cold Storage of Nagpore Oranges', Misc. Bull. No. 49, Imp. Conn. Agric. Res., Govt. of India, New Delhi, 1942.

Khan, A.H., 'The Cold Storage of Citrus Fruits', Punjab Fruit Jr. 5 : 900-02, 1941.

Laudel, R.D., 'Commodity Market Dynamics : A Systems Analysis of Fundamental Relationships', Ph.D. Thesis, Gregoria Institute of Technology, 1970.

Lal Singh, and Hamid, A., 'The Cold Storage of Fruits in the Punjab', Indian Jr. Agric. Sci. 12:757-78, 1942.

McMillan, C. & R.F. Gonzalez, 'Systems Analysis : A Computer Approach to Decision Models', Revised Edition, Richard, D. Irwin, Inc., Homewood, Illinois, 1968.

Naylor, T.H., etal, 'Computer Simulation Techniques', Jhon Wiley & Sons, Inc., New York, 1966.

Packer, D.W., 'Resource Acquisition in Corporate Growth', M.I.T. Press, Cambridge, Massachusetts, 1964.

Parvin, D.W., Jr., '<u>Effects of Weather on Orange Supplies</u>', Ph.D. Thesis, University of Florida, 1971.

Penappa, K.N., '<u>Final Report of Orange Marketing Scheme in the</u> Province of Coorg', I.C.A.R., New Delhi, 1949.

Rausser, G.C., '<u>A Dynamic Econometric Model of the California-Arizona Orange Industry</u>', Ph.D. Thesis, University of California, Davis, 1971.

'New Directions in Industrial Dynamics', <u>Industrial Management Review</u>, VI, No. 1, Alfred P. Sloan School of Management, M.I.T. (Fall 1964).

Trelogan, H.C., 'On Benefits of Agricultural Marketing Research', <u>Jr. of Farm Economics</u>, 47, No. 1, Feb. 1965, pp 36-50.

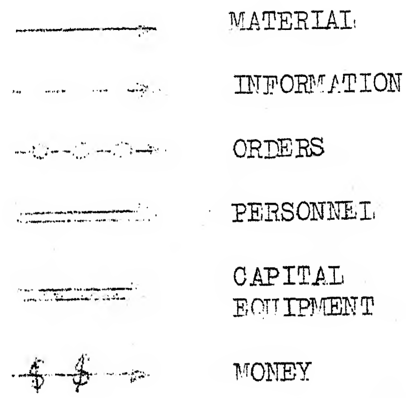
Weymar, F.H., '<u>Industrial Dynamics : Inter-action Between the Firm and its Markets</u>', ed. by Wroe Aldenson & Stanley Shapiro, Marketing and the Computer, Englewood Cliffs, New Jersey, Prentice Hall, 1963, pp 260-276.

<u>APPENDIX A</u>

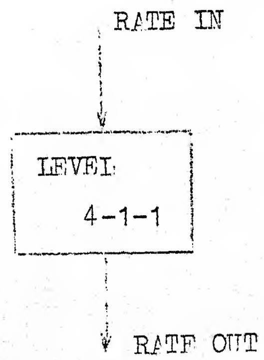
FLOW DIAGRAM SYMBOLS FOR INDUSTRIAL DYNAMICS

The system of symbols used in Industrial Dynamics show the existence of the interrelationships in the system. It discloses what factors enter into each decision (rate) function. For the specific nature of interactions between the factors entering into a decision the diagram carries the equation numbers which is a pointer to the pertinent equation.

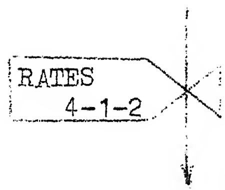
1. FLOWS indicate the medium in which the dynamic behavior is being reflected



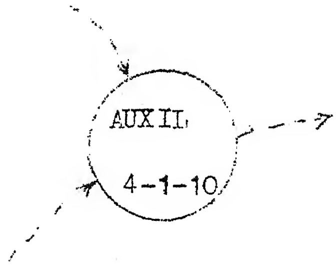
2. A LEVEL portrays an accumulation created by a delay separating the flows into and from the level. The equation number linking the diagram to the equations is in the lower-right corner.



3. A RATE equation determines the rate of flow within the model. Rate equations are the decision functions

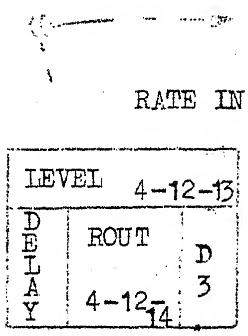


4. AUXILIARY VARIABIES are used to simplify the formulations within the model.

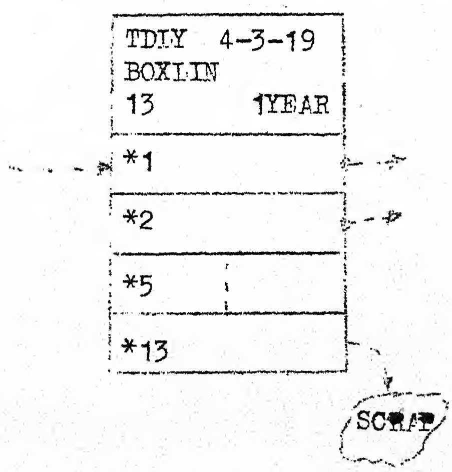


5. PARAMETERS are the values assumed constant for the simulation run.

6. Exponential DELAYS are a combination of levels and rates of flow. A THIRD ORDER DELAY function contains three levels with interconnecting rates. In the box D3 indicates a third order delay D1 would indicate a first-order delay.



7. BOXCARS : For many purposes involving historical situations, it is desired to segregate past information. For this either a linear or a cyclic 'boxcartrain' is used. The symbol contains the name, type, number of box cars along with the equation number and shifting interval.



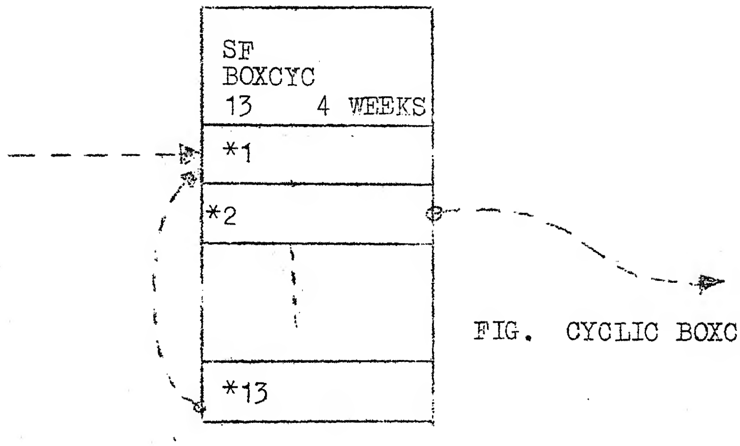
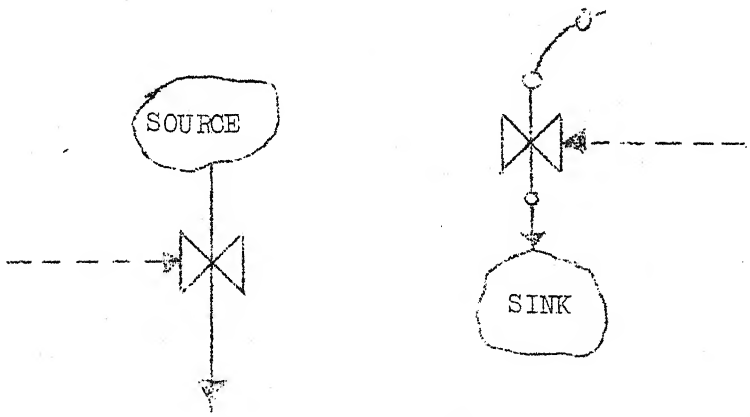


FIG. CYCLIC BOXCAR TRAIN

8. SOURCE and SINKS are used to mark the boundary of the model.



APPENDIX B

SCALING LETTERS*

There are several instances when DYNAMO uses a single letter following a number to indicate the scaling DYNAMO has applied to that number. One such instance occurs in the tabulated results when the user has specified the scaling, and the number with that scaling exceeds 5 significant figures. Under these circumstances DYNAMO replaces the fifth digit with such a scaling letter. These letters have the following significance :

Letter	Multiply Printed Results by	or	Consider Value Expressed in
A	10^{-3}		thousandths
B	10^{9}		billions
C	10^{27}		octillions
D	10^{33}		decillions
E	10^{-6}		millionths
F	10^{-9}		billionths
G	10^{-12}		trillionths
H	10^{-15}		quadrillionths
J	10^{-18}		quintillionths
K	10^{-30}		(off scale)
L	10^{-21}		sextillionths
M	10^{6}		millions
N	10^{30}		nonillions
P	10^{24}		septillions
Q	10^{15}		quadrillions
R	10^{12}		trillions
S	10^{21}		sextillions
T	10^{3}		thousands
U	10^{-24}		septillionths
V	10^{18}		quintillions
W	10^{-27}		octillionths
X	1		units
Y	10^{-30}		nonillionths
Z	10^{33}		(off scale)

* Reproduced from User's Manual by Pugh (16).

APPENDIX C

SIMULATION RESULTS

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPROI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.0 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.800	2.07	-1.444
52.00	900.0 786.48	12.183 14.713	175.3 900.0	0. 186.92	0. 3594.5	1052.3 163.64	504.08	209.14	124.48	5000.0	28.600	150.40	27.057
104.00	1007.2 830.20	13.068 15.531	586.7 1052.3	0. 197.41	0. 3796.3	1109.1 183.12	589.28	259.79	127.24	5000.0	28.600	182.91	25.393
156.00	737.7 748.75	11.690 13.931	1030.7 1109.1	0. 79.89	0. 1536.3	1154.2 134.13	578.98	245.04	133.39	5000.0	28.600	178.40	31.250

TABLE-1

PL=P, PLCTR=L, PLFF=F, PLAS=S

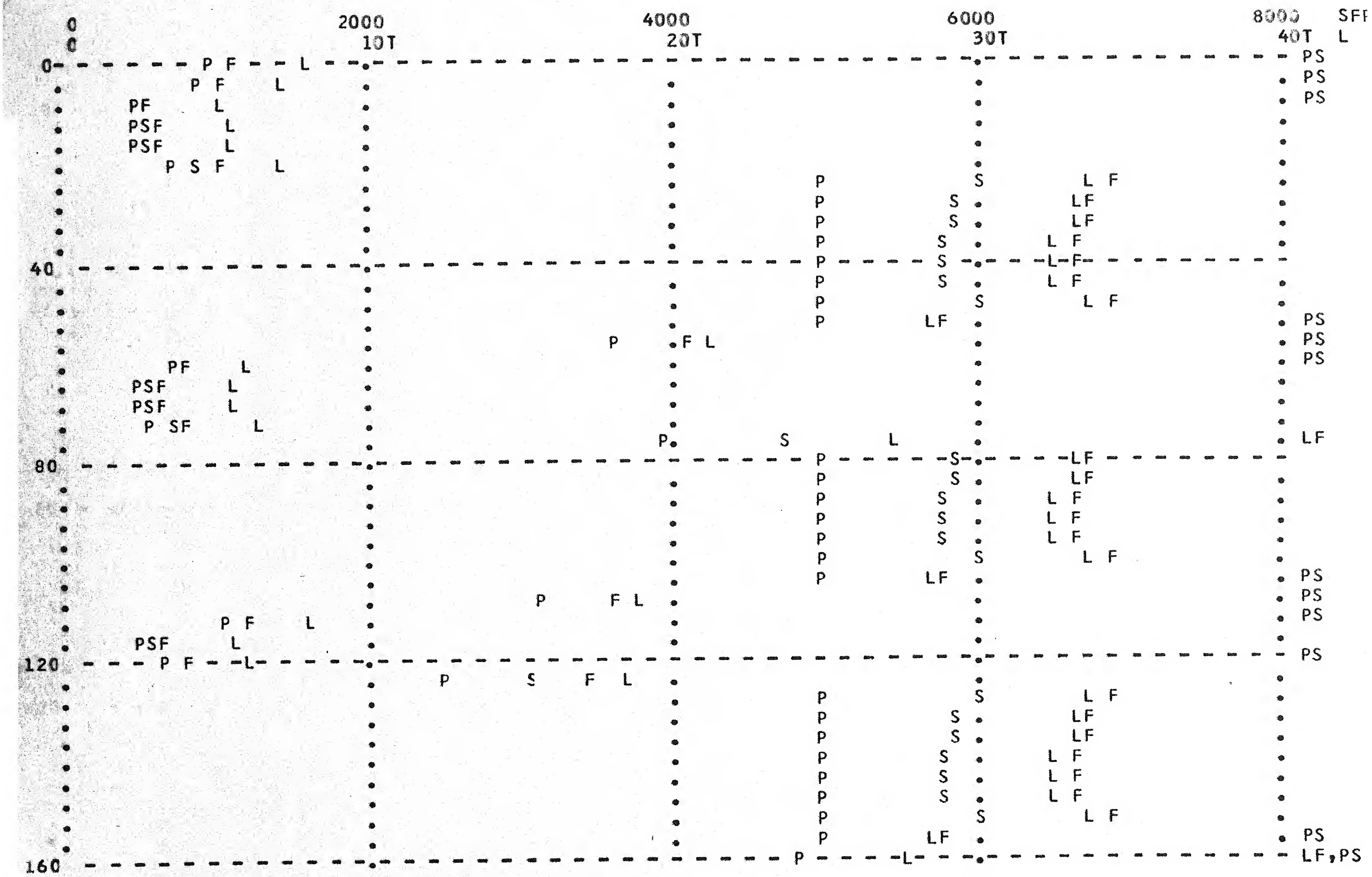
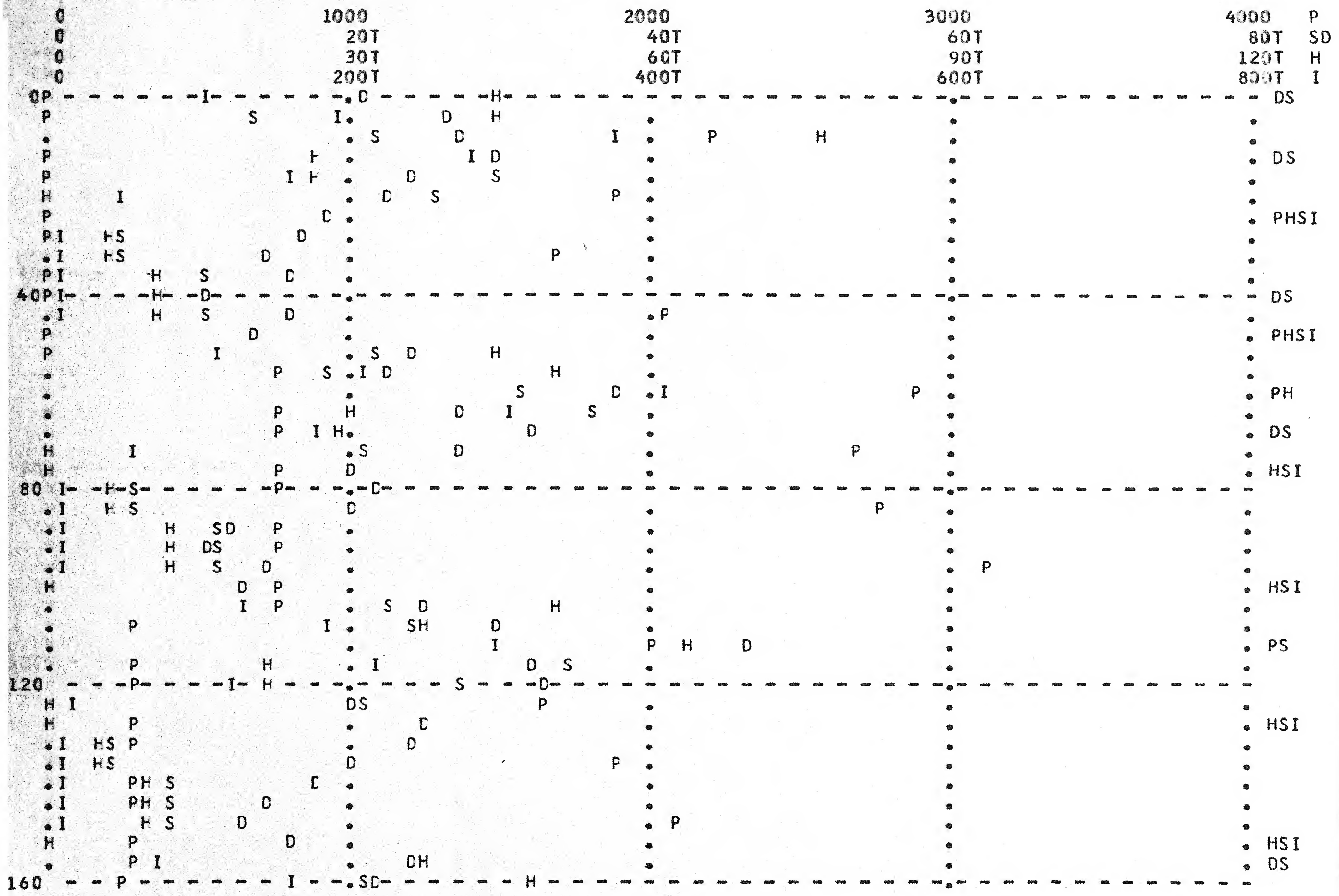
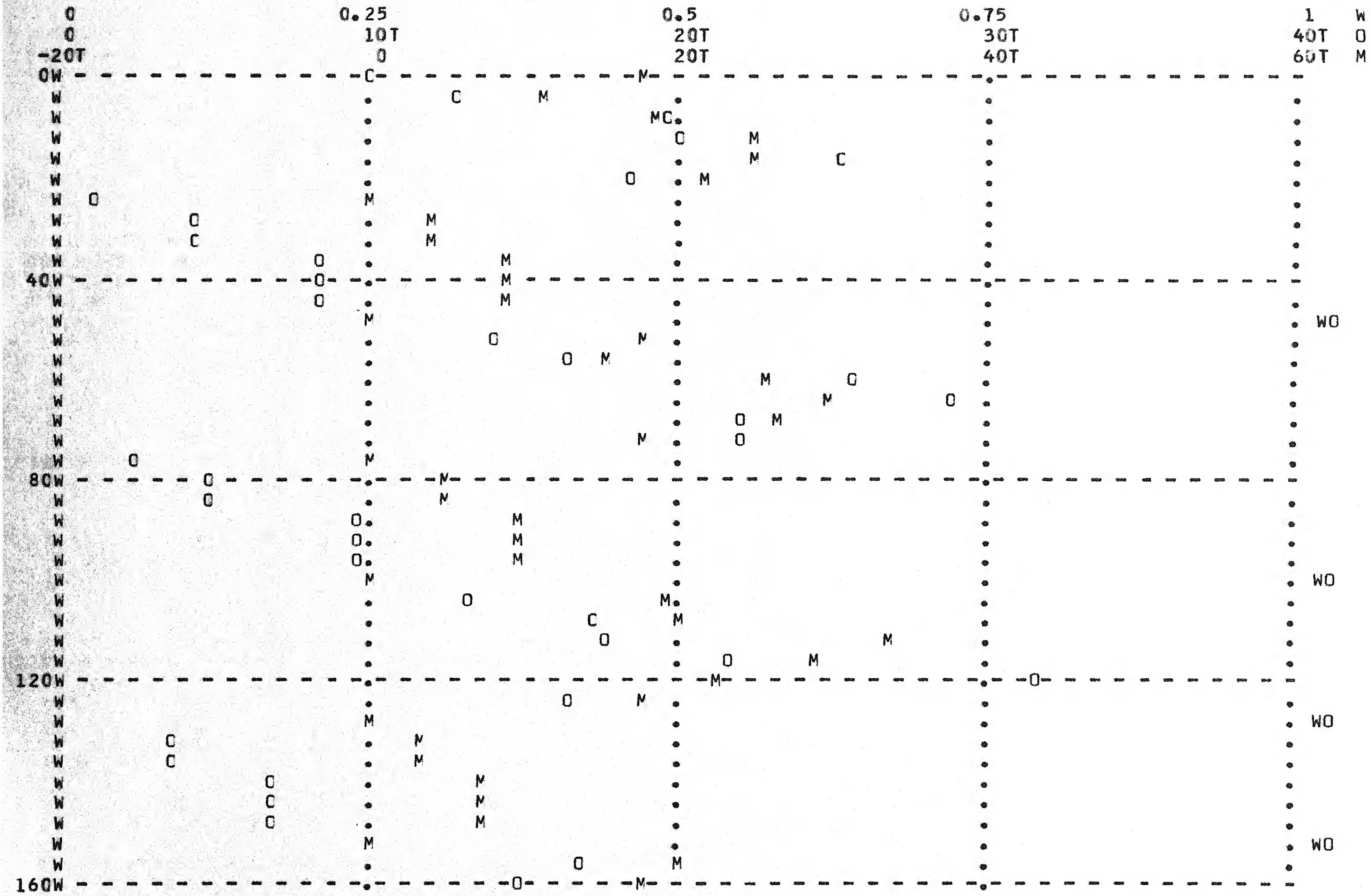


Fig.1

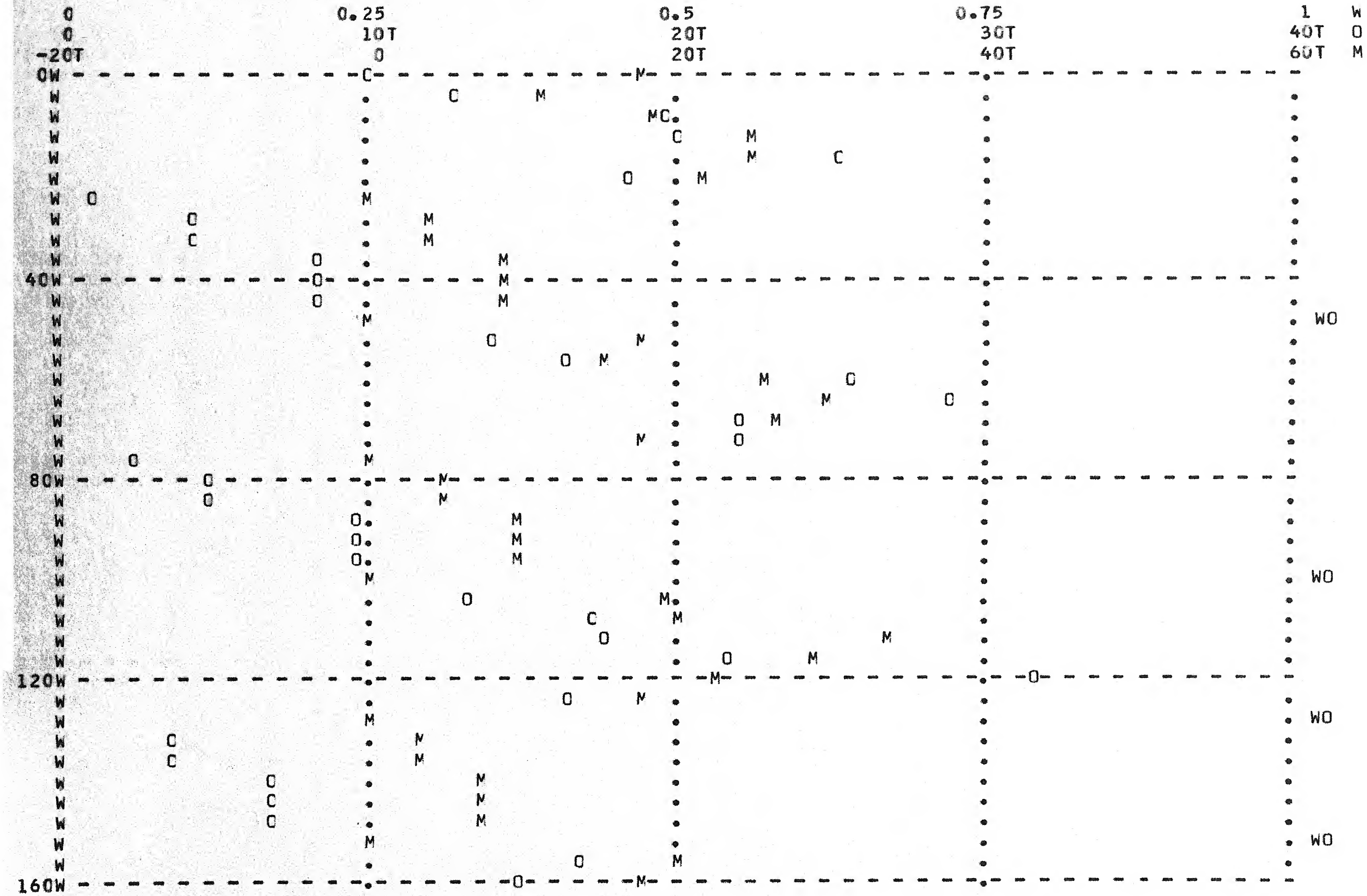
P=P, H=H, D=D, S=S, I=I


0 1000 2000 3000 4000 P
0 20T 40T 60T 80T SD
0 30T 60T 90T 120T H
0 200T 400T 600T 800T I
0
40
80
120
160
DS
PHSI
PH
HSI
PS

MCST=M, MWCS=W, SOR=O



MCST=M, MWCS=W, SOR=O



PAGE 227 SNK195

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

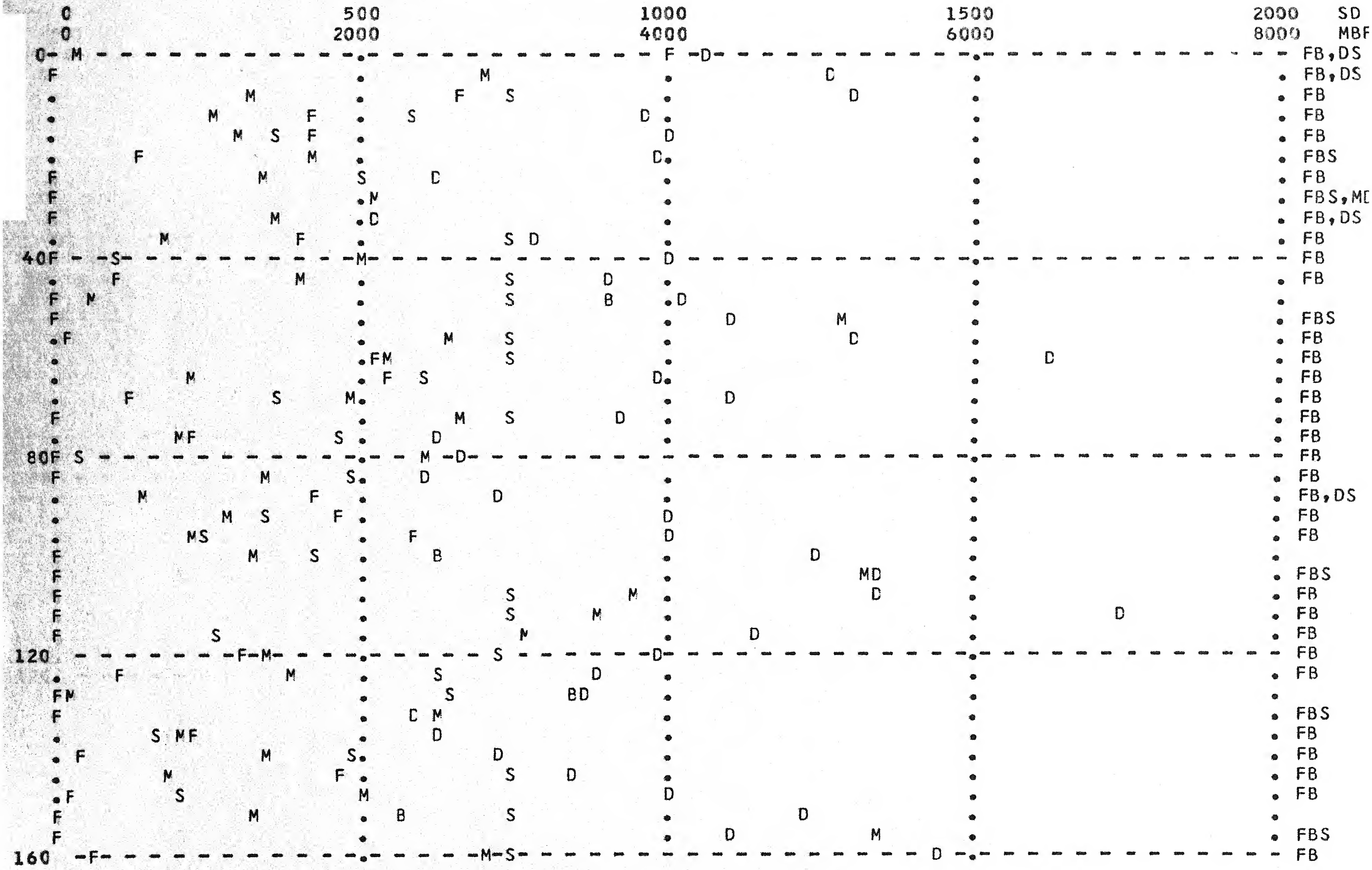


Fig. 4

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

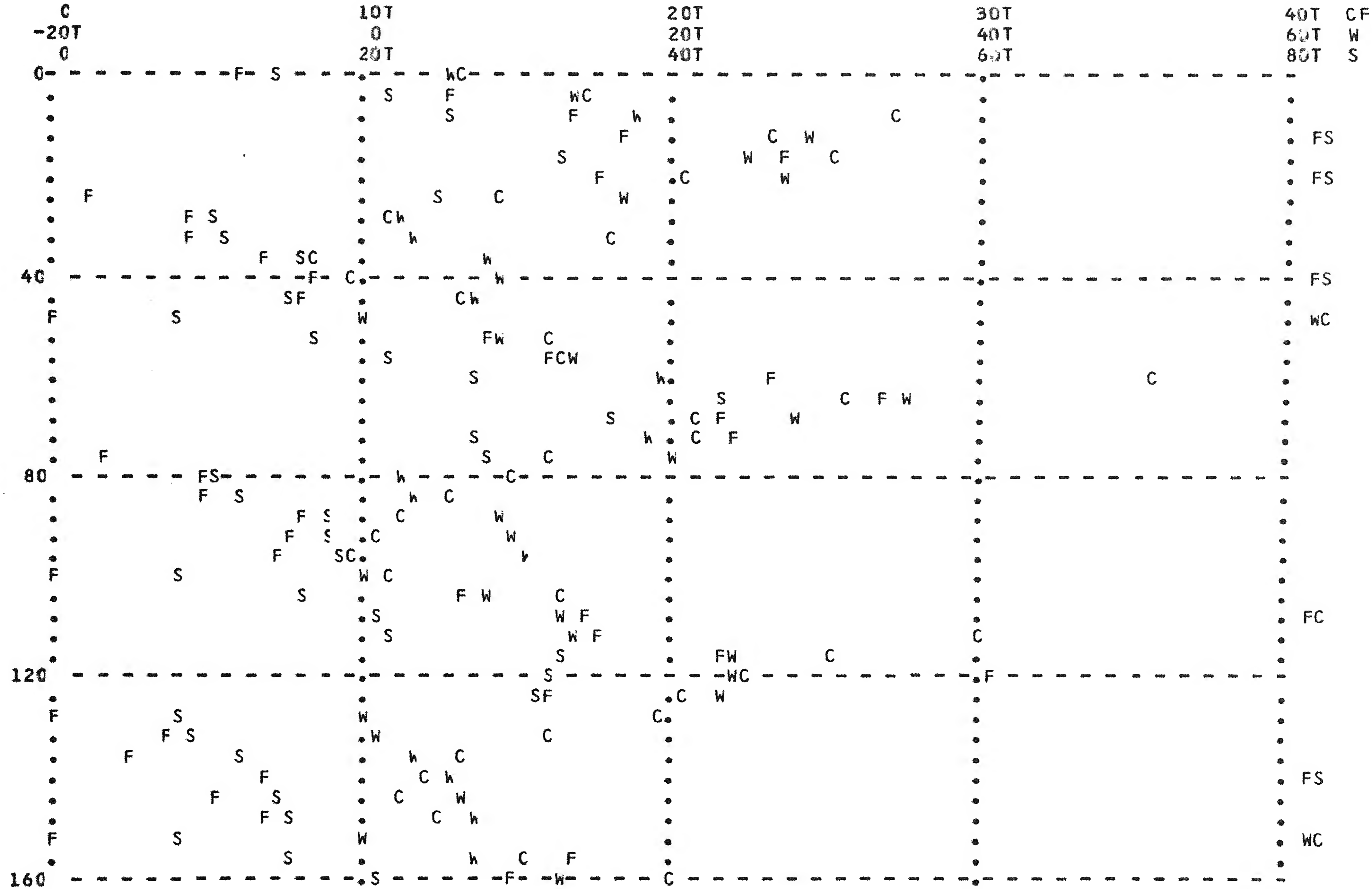


Fig. 5

PAGE 229 SNK195

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

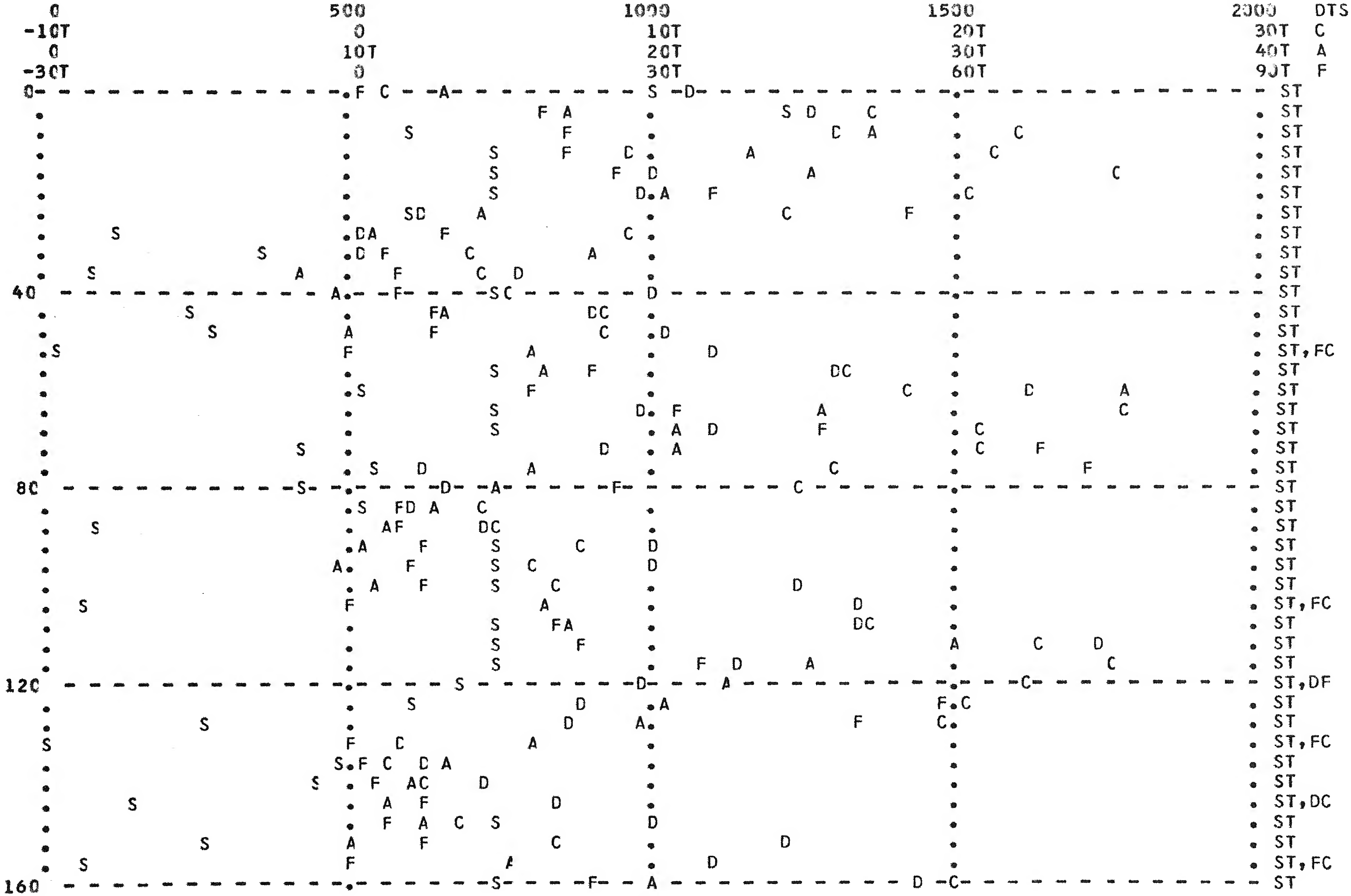


Fig. 6

	TT
SNK185	5.TT
DECK01	5.TT

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPRCI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.0 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.800	2.07	-1.444
52.00	900.0 786.18	12.178 14.707	174.9 900.0	0. 187.36	0. 3603.0	1051.2 163.64	488.23	203.13	122.82	5000.0	28.600	146.92	22.339
104.00	1007.2 831.07	13.076 15.547	586.1 1051.2	0. 199.51	0. 3836.7	1112.0 183.12	568.16	249.92	120.65	5000.0	28.600	180.21	23.313
156.00	737.7 750.72	11.722 13.969	1031.0 1112.0	0. 75.02	0. 1442.7	1153.3 134.13	551.91	235.27	130.93	5000.0	28.600	168.26	26.539

TABLE-2

PAGE 216 SNK185

PL=P, PLCTR=L, PLFF=F, PLAS=S

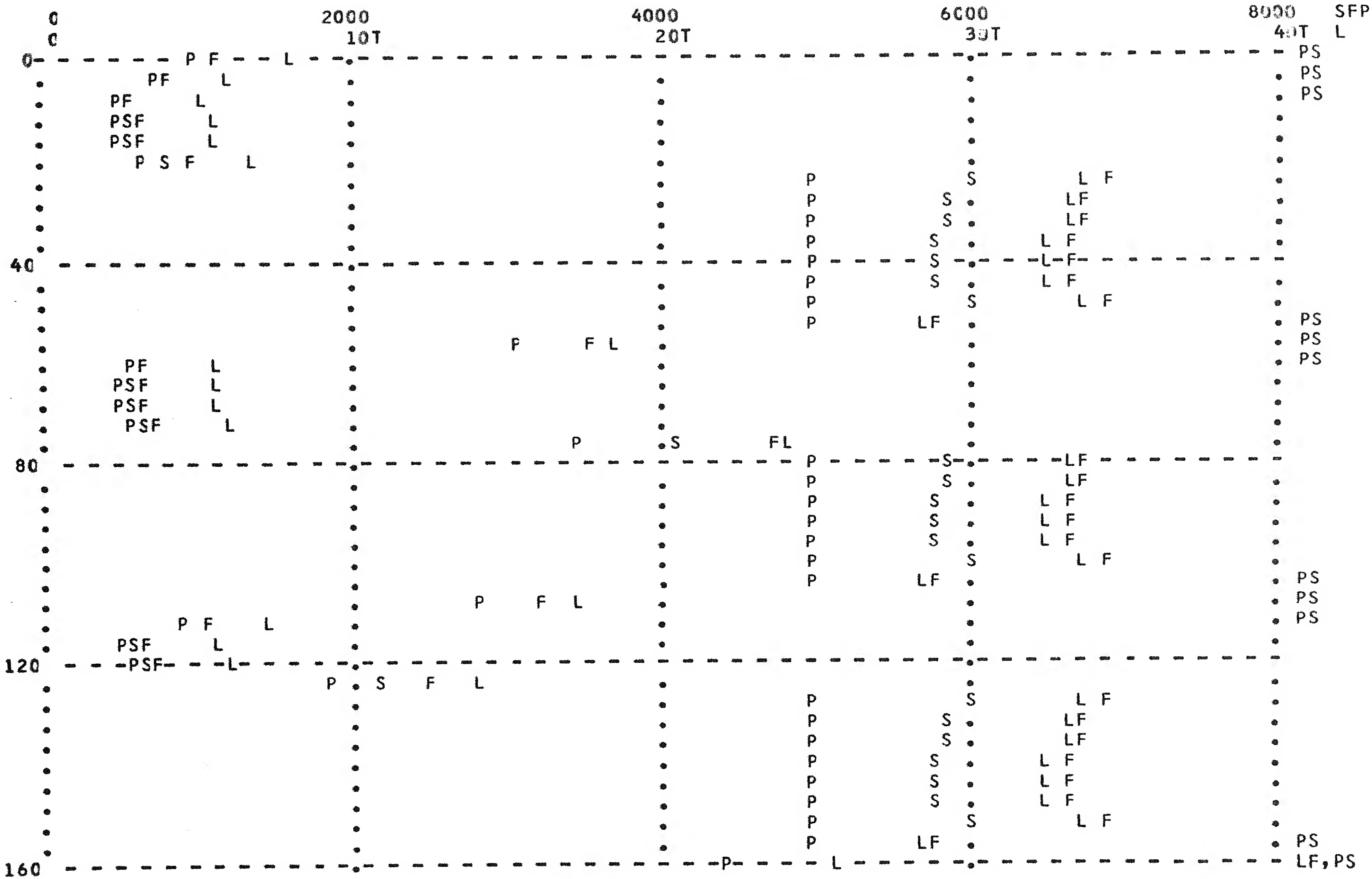


Fig. 7

P=P, H=H, D=C, S=S, I=I

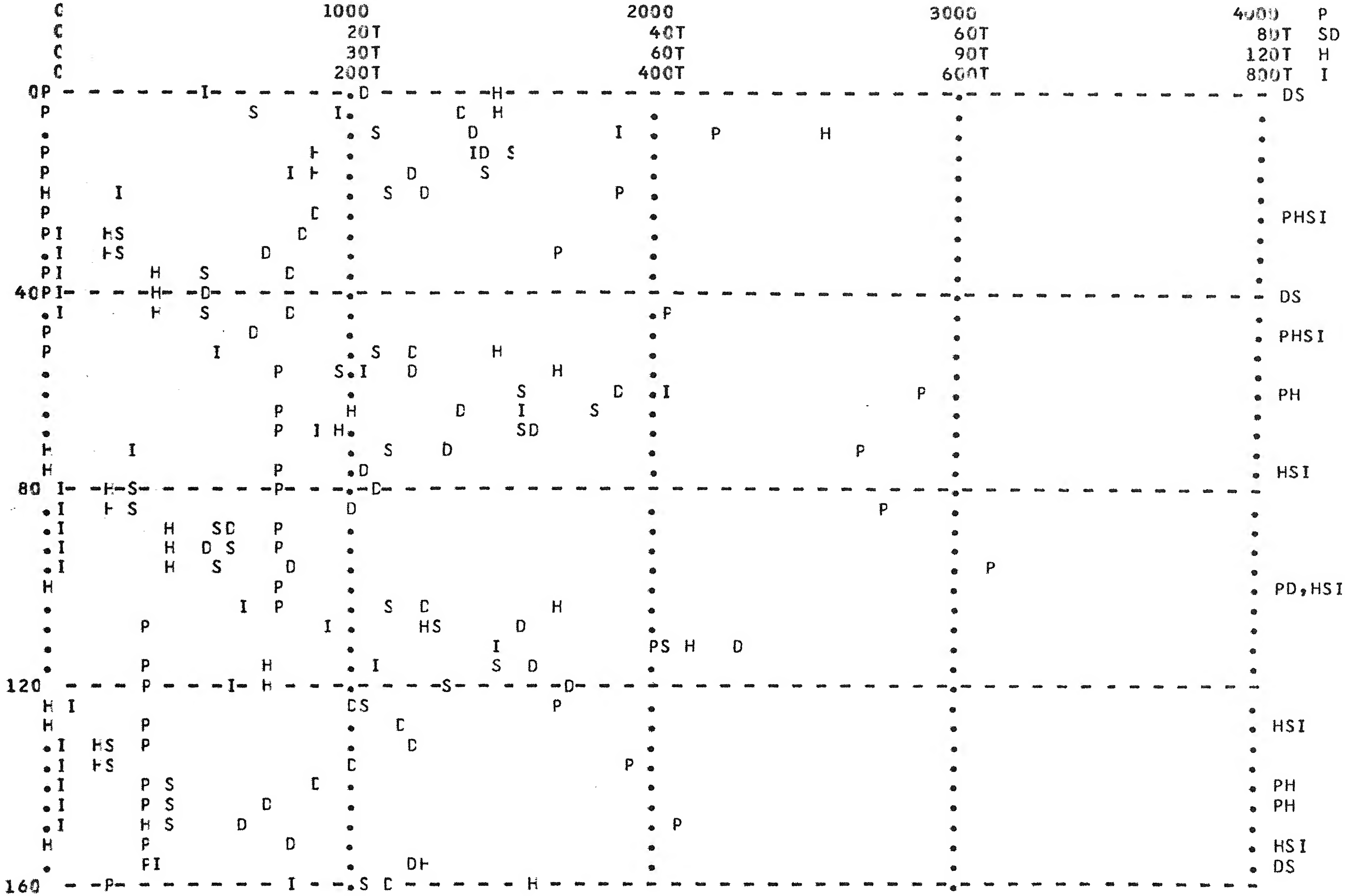


Fig. 8

MCST=M, MWCS=W, SOR=C

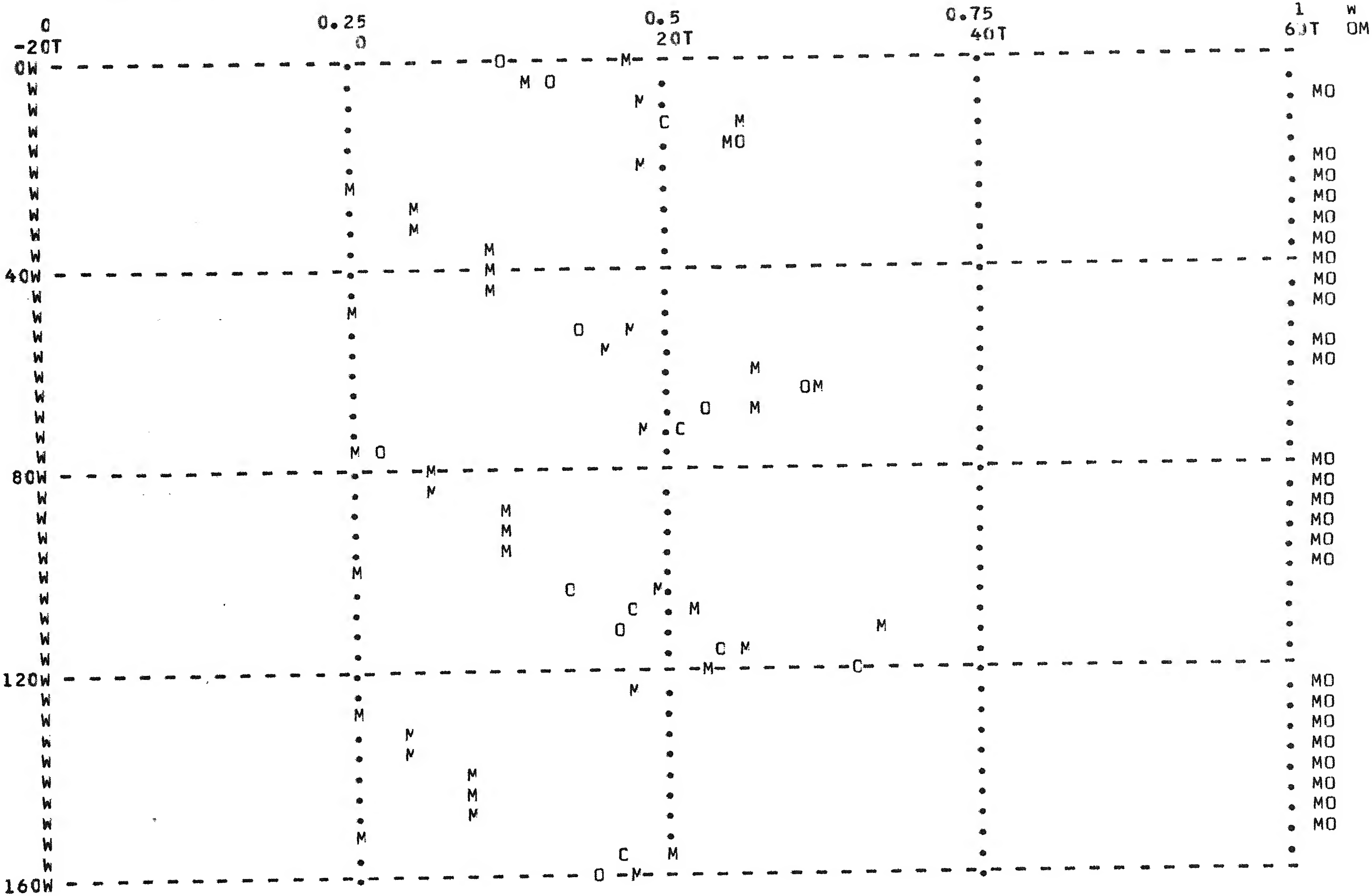


Fig.9

PAGE 219 SNK185

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

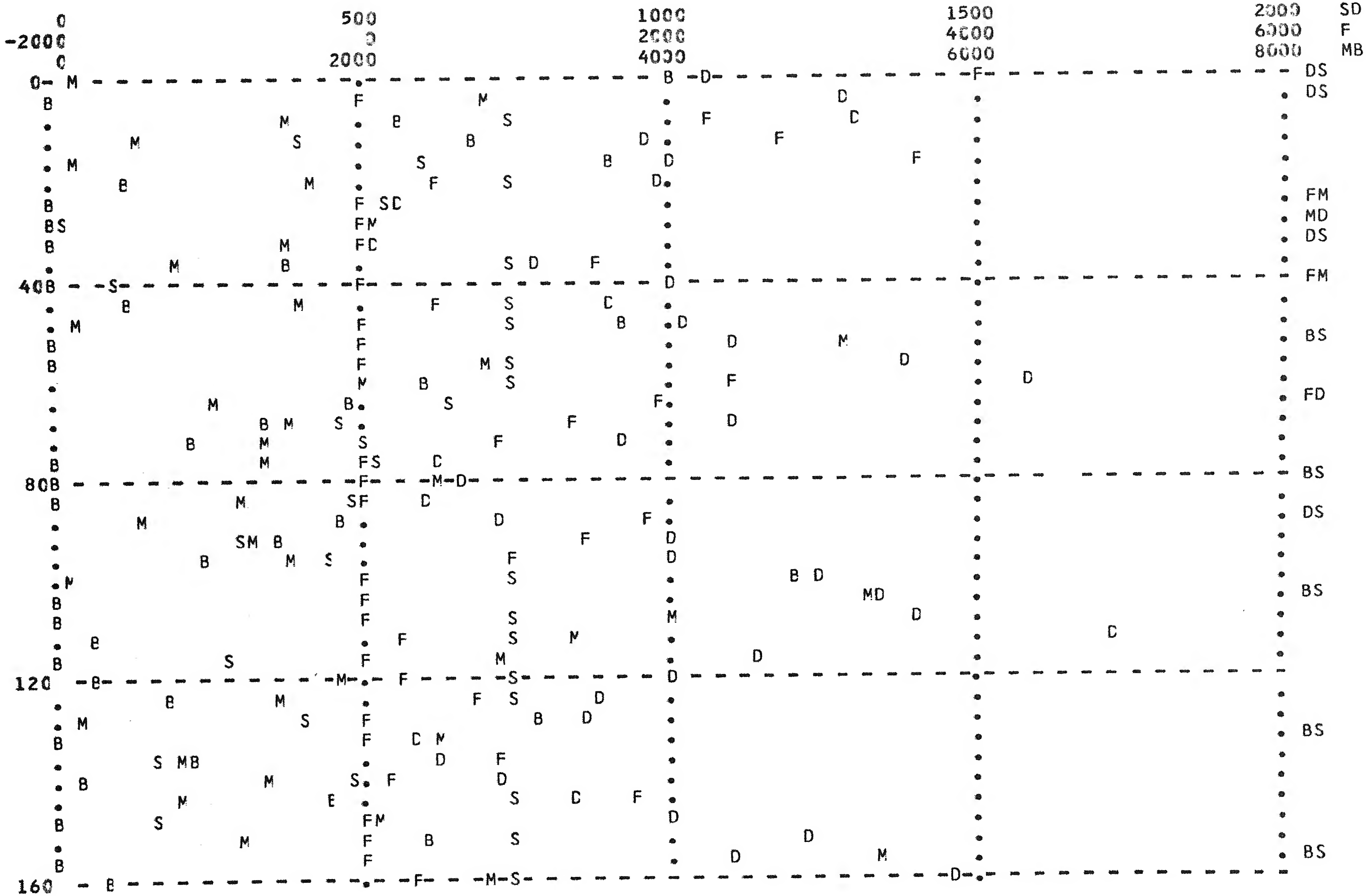


Fig.10

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

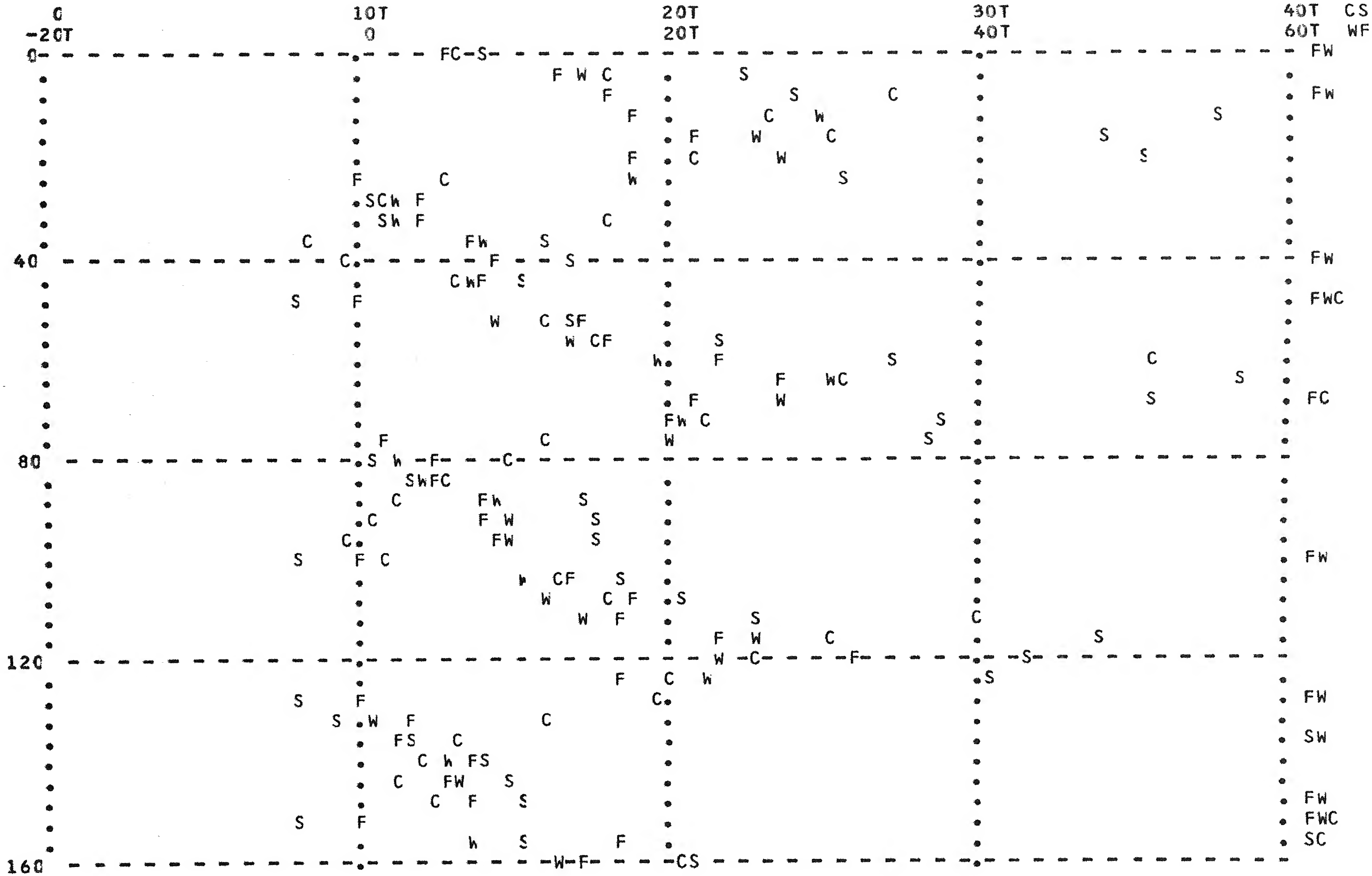


Fig. 11

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

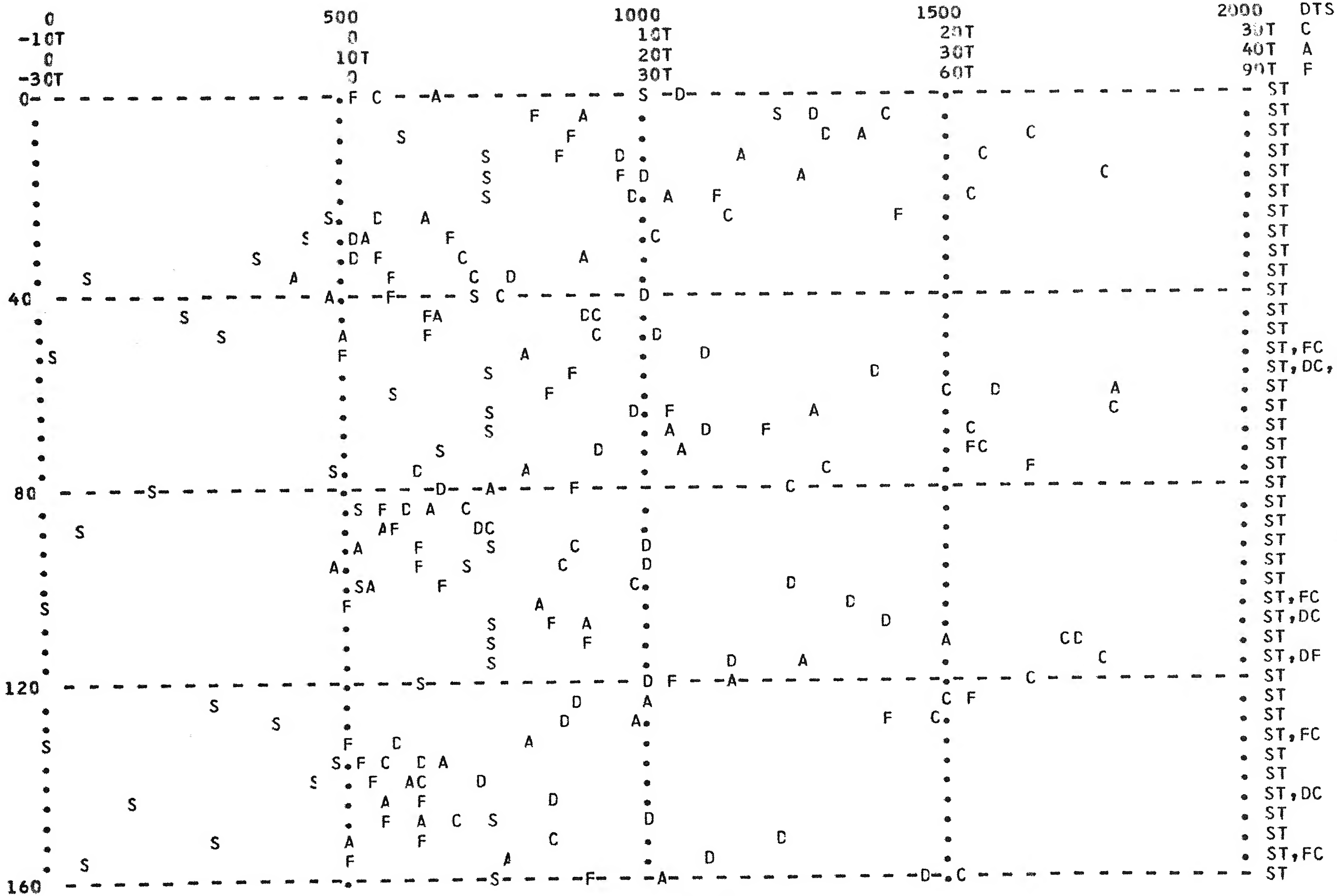


Fig. 12

	TT
SNK175	6.TT
DECK01	5.TT

TIME	TACAH ISGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPRCI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.0 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.600	2.07	-1.444
52.00	900.0 786.31	12.182 14.710	175.6 900.0	0. 186.21	0. 3581.0	1052.1 163.64	523.37	215.14	130.98	5000.0	28.600	153.94	31.235
104.00	1007.2 832.35	13.100 15.572	586.9 1052.1	0. 197.65	0. 3601.0	1111.3 183.12	620.03	273.87	131.68	5000.0	28.600	190.63	29.846
156.00	737.7 749.75	11.707 13.951	1031.2 1111.3	0. 77.30	0. 1486.5	1155.5 134.13	620.78	265.00	138.04	5000.0	28.600	191.73	35.118

TABLE-3

PL=P, PLCTR=L, PLFF=F, PLAS=S

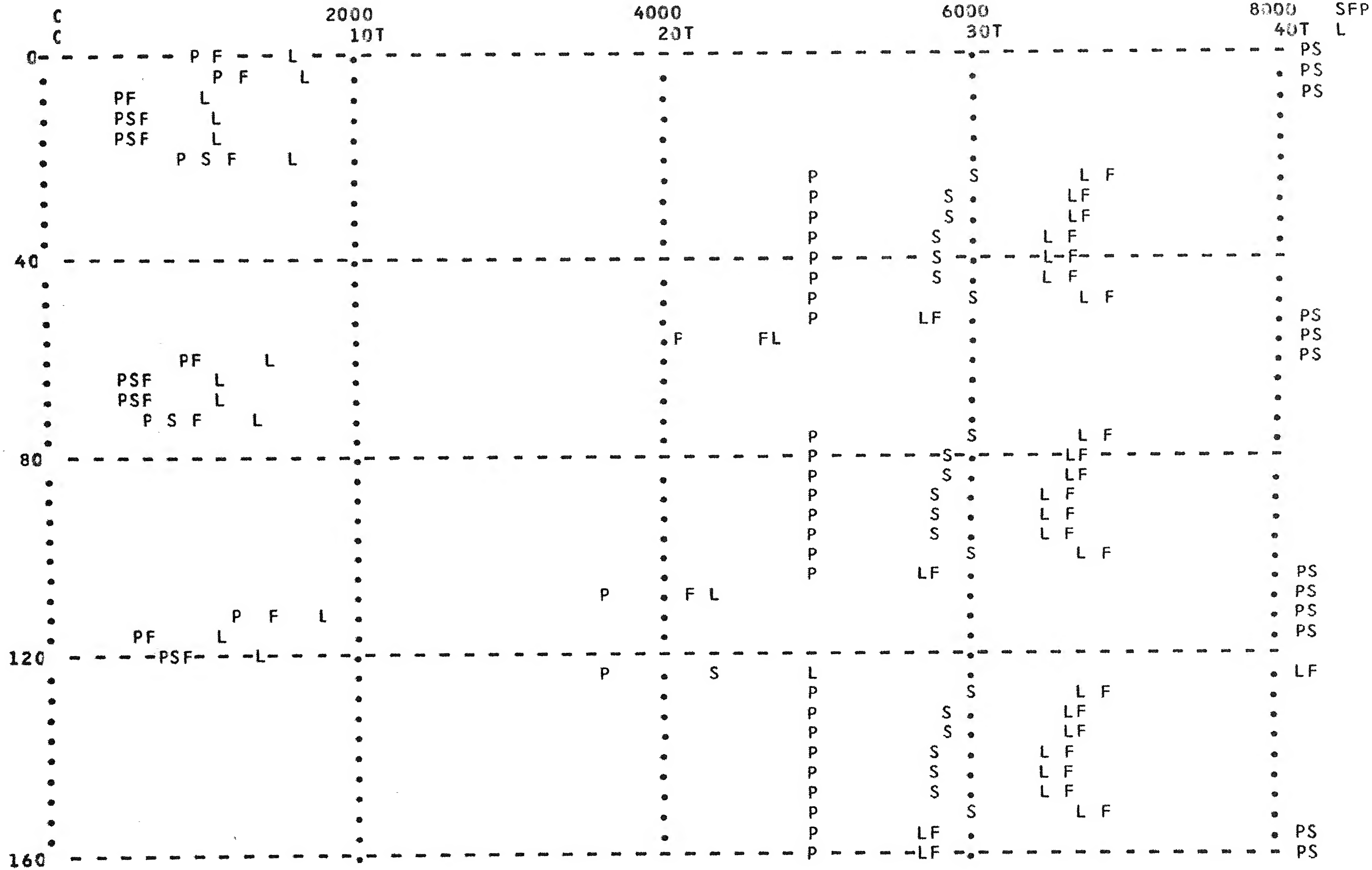


Fig. 13

P=P, H=H, D=D, S=S, I=I

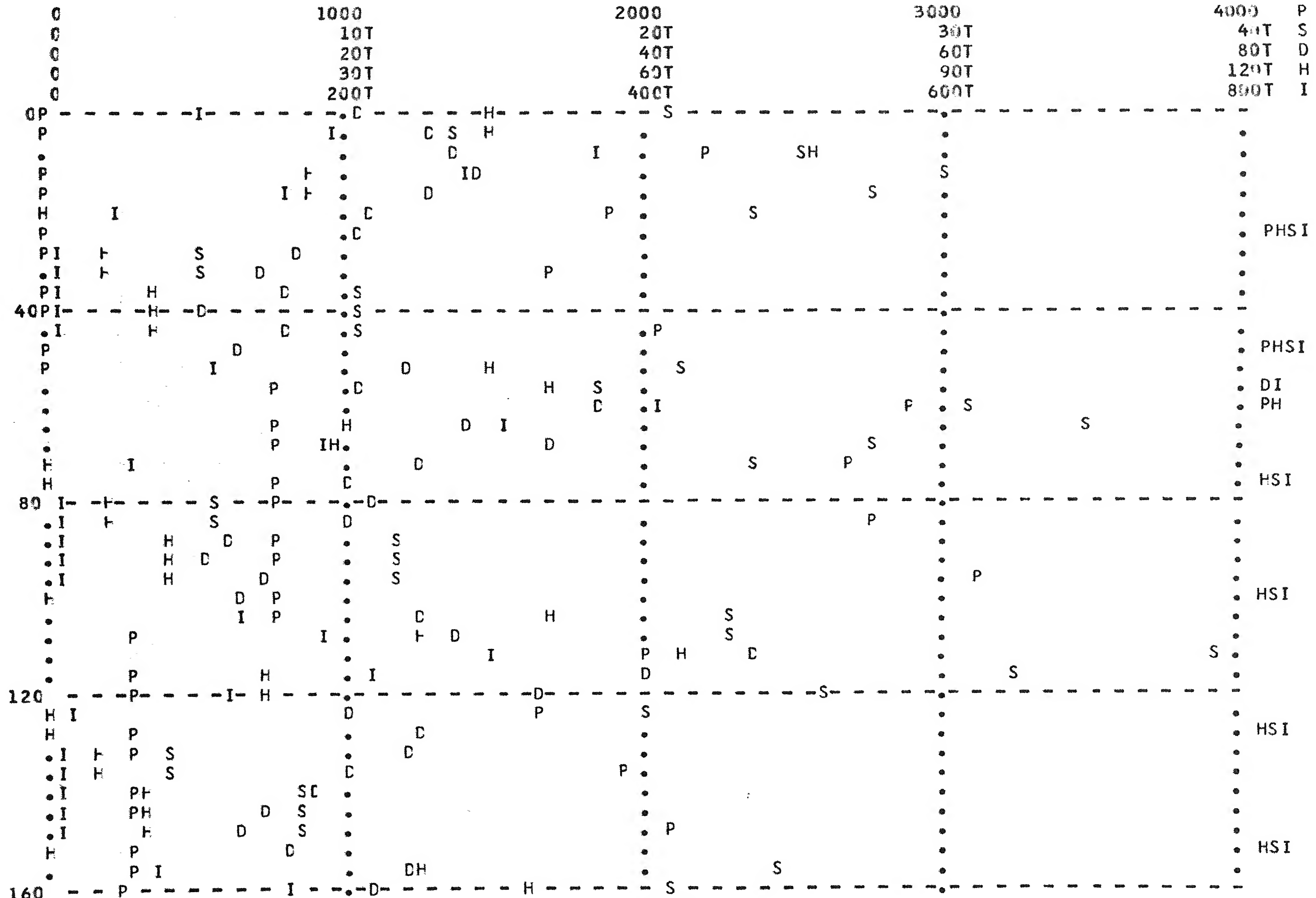


Fig 14

MCST=M, MWCS=W, SOR=C

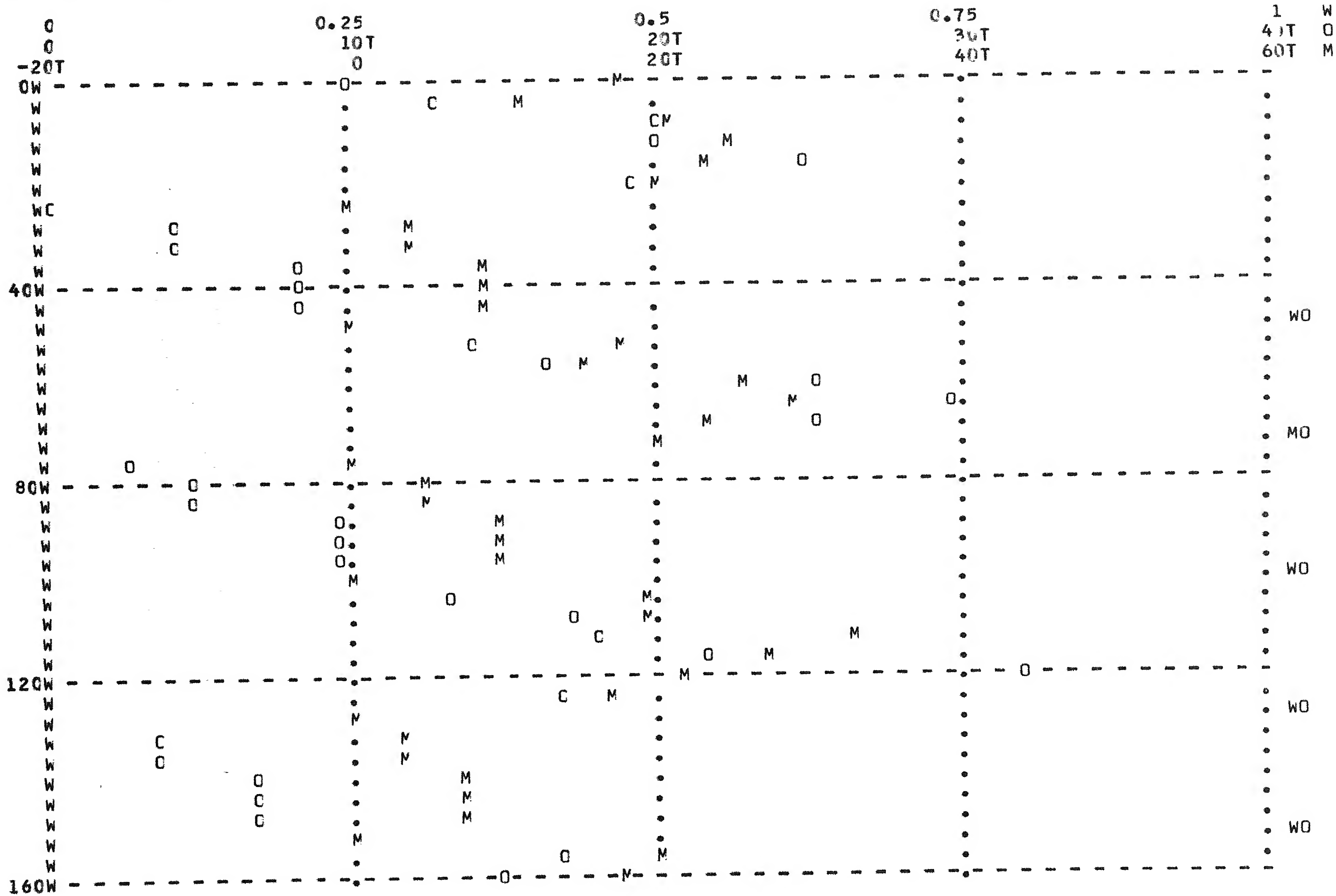


Fig.15

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

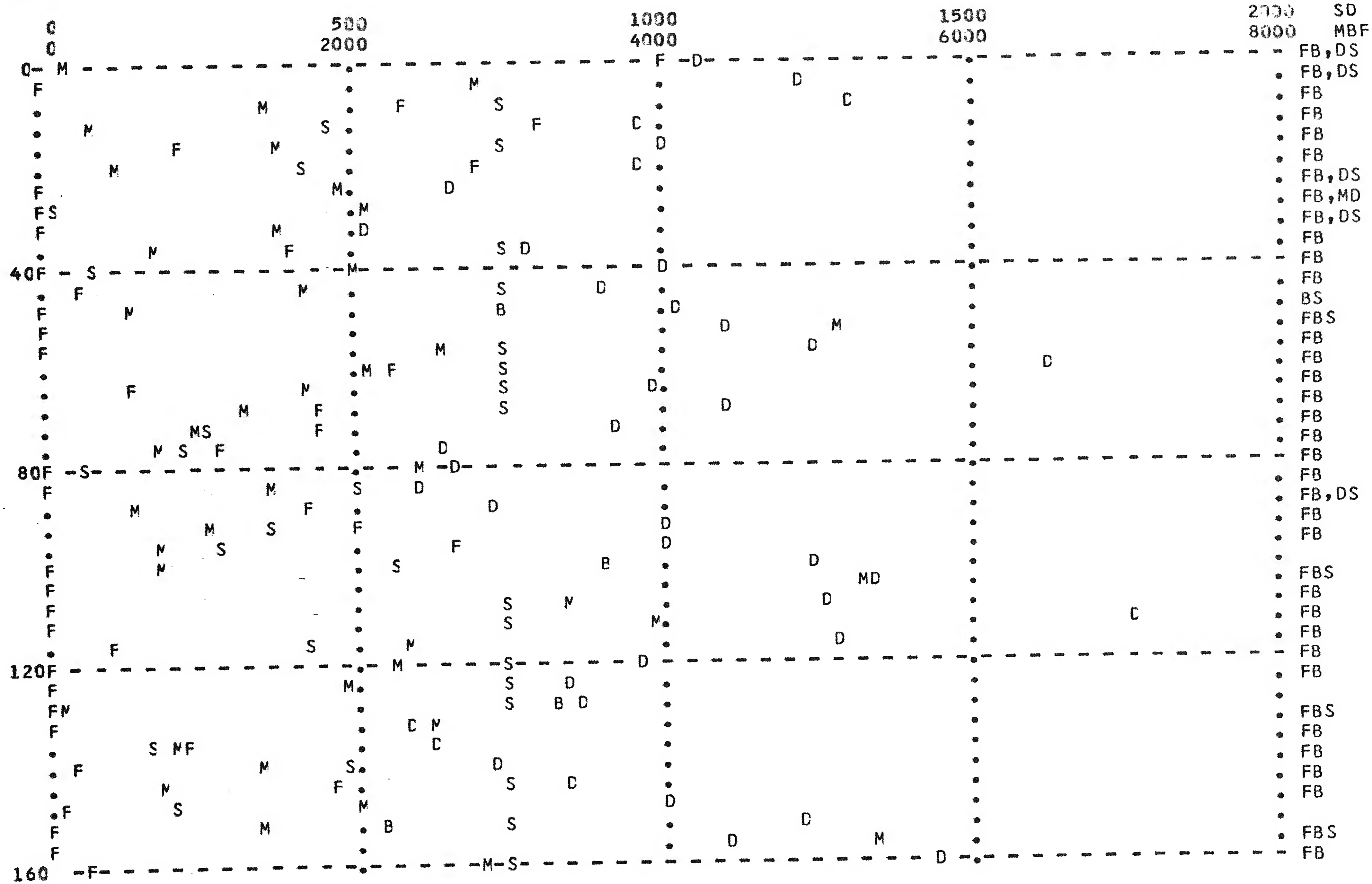


Fig. 16

PAGE 212 SNKI75

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

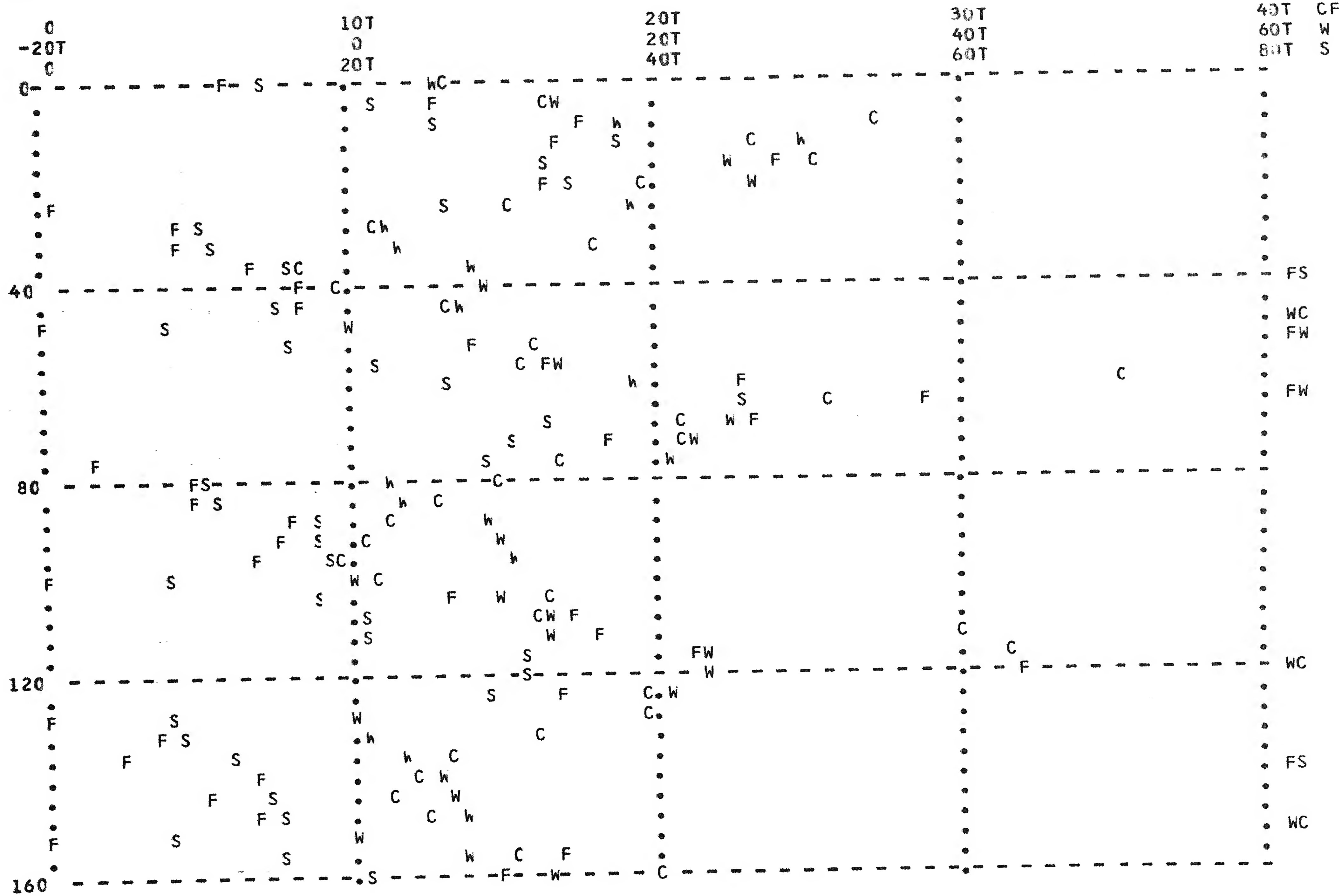


Fig.17

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

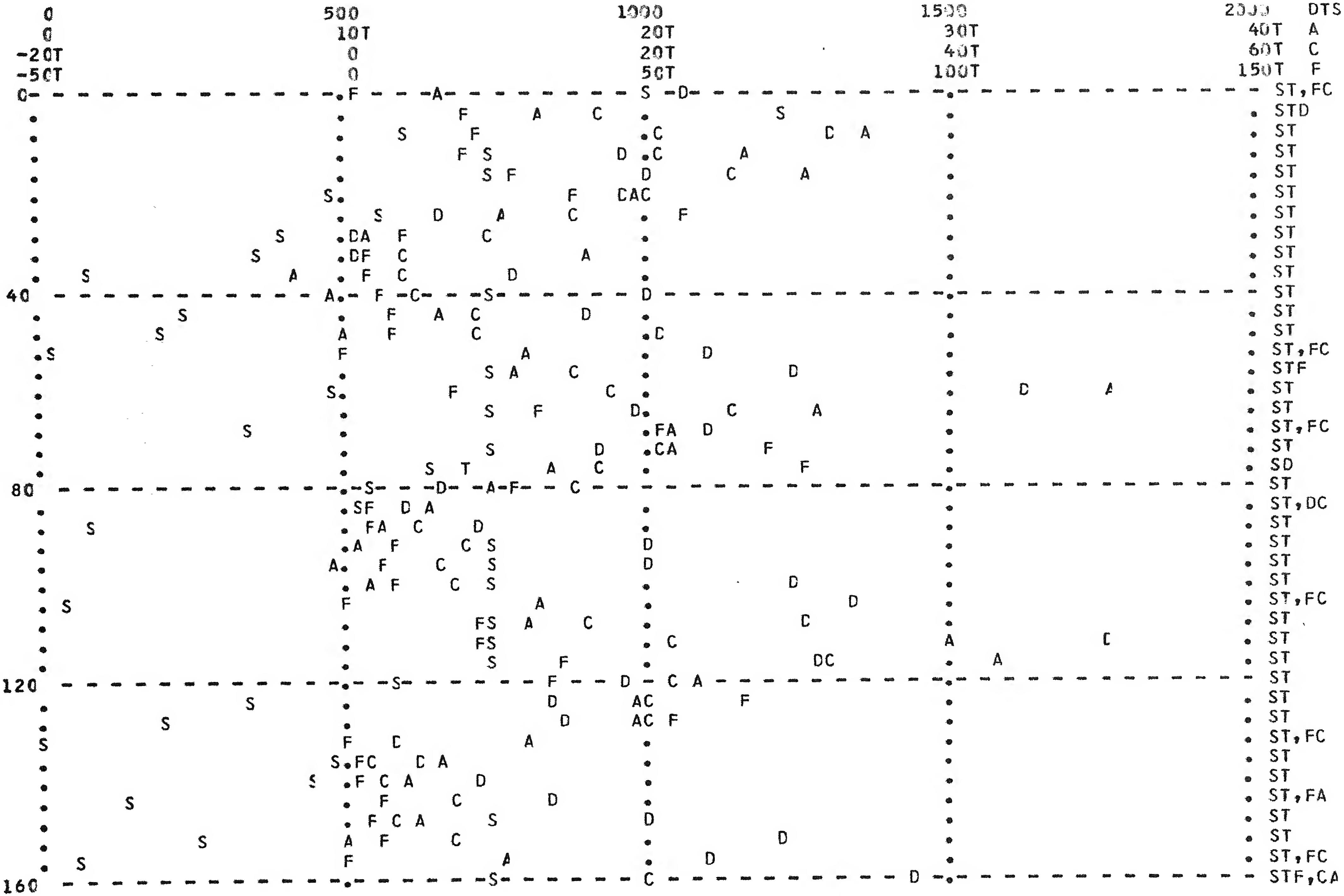


Fig. 18

	WCLS	WCLSG
SNK155	.0000	.0000
DECKC1	.2000	.4000

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPROI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+00	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.7	.000 .000	.00 900.0	0. 0.	0. 0.	900.0 190.91	.00	.14	1.97	1000.0	7.600	2.07	-1.444
52.00	900.0 973.6	15.182 18.311	110.83 900.0	0. 0.	0. 0.	1054.7 163.64	467.80	207.67	102.08	5000.0	28.600	144.31	23.929
104.00	1007.2 1028.3	16.241 19.340	370.85 1054.7	0. 0.	0. 0.	1112.7 183.12	548.85	248.89	103.83	5000.0	28.600	182.2[illegible]	3[illegible].751
156.00	737.7 830.8	12.999 15.508	690.27 1112.7	0. 0.	0. 0.	1149.6 134.13	552.49	238.59	127.40	5000.0	28.600	174.05	21.416

TABLE-4

PL=P, PLCTR=L, PLFF=F, PLAS=S

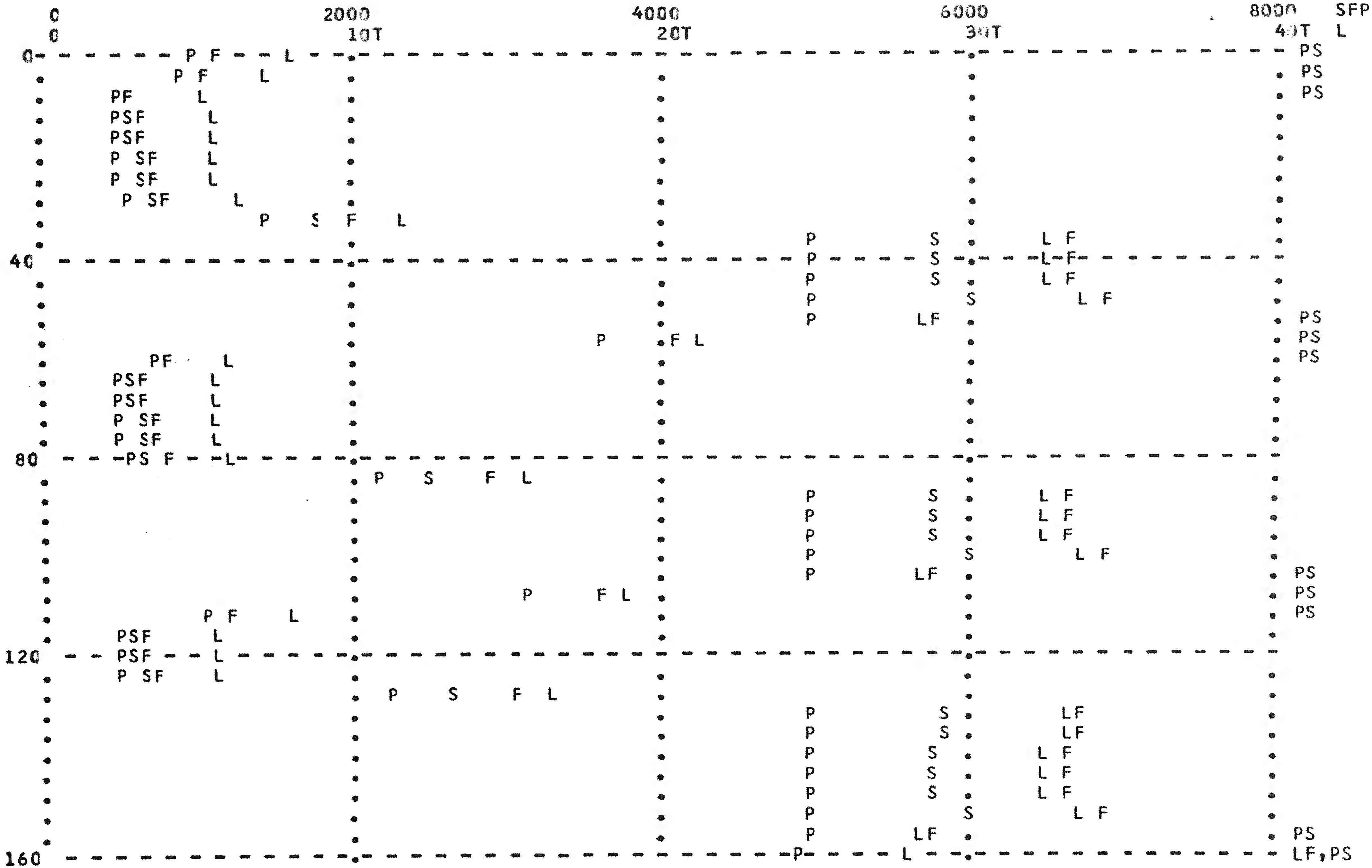


Fig. 19

PAGE 193 SNKI55

P=P, H=H, D=C, S=S, I=I

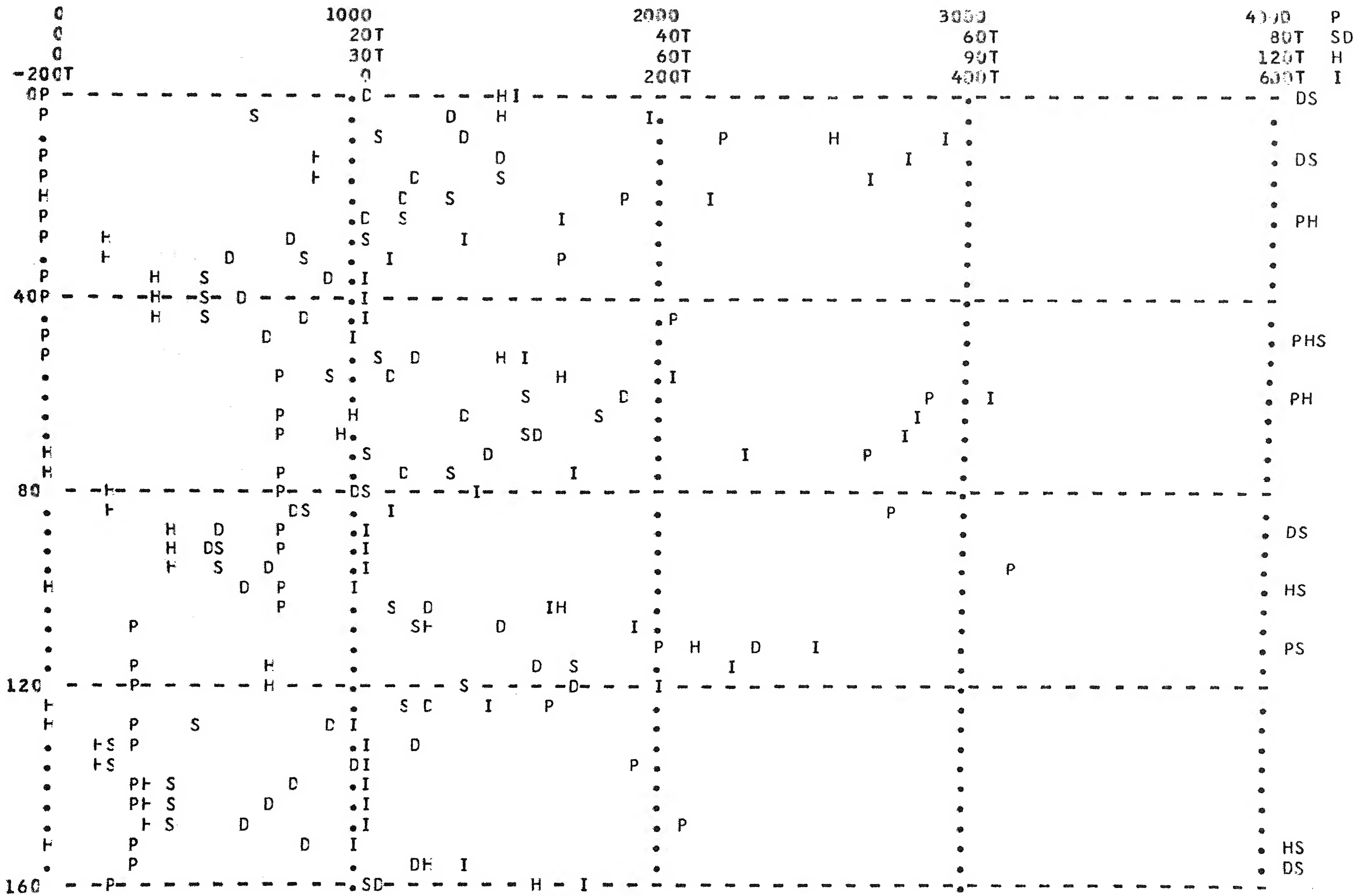


Fig. 20

MCST=M, MWCS=W, SOR=O

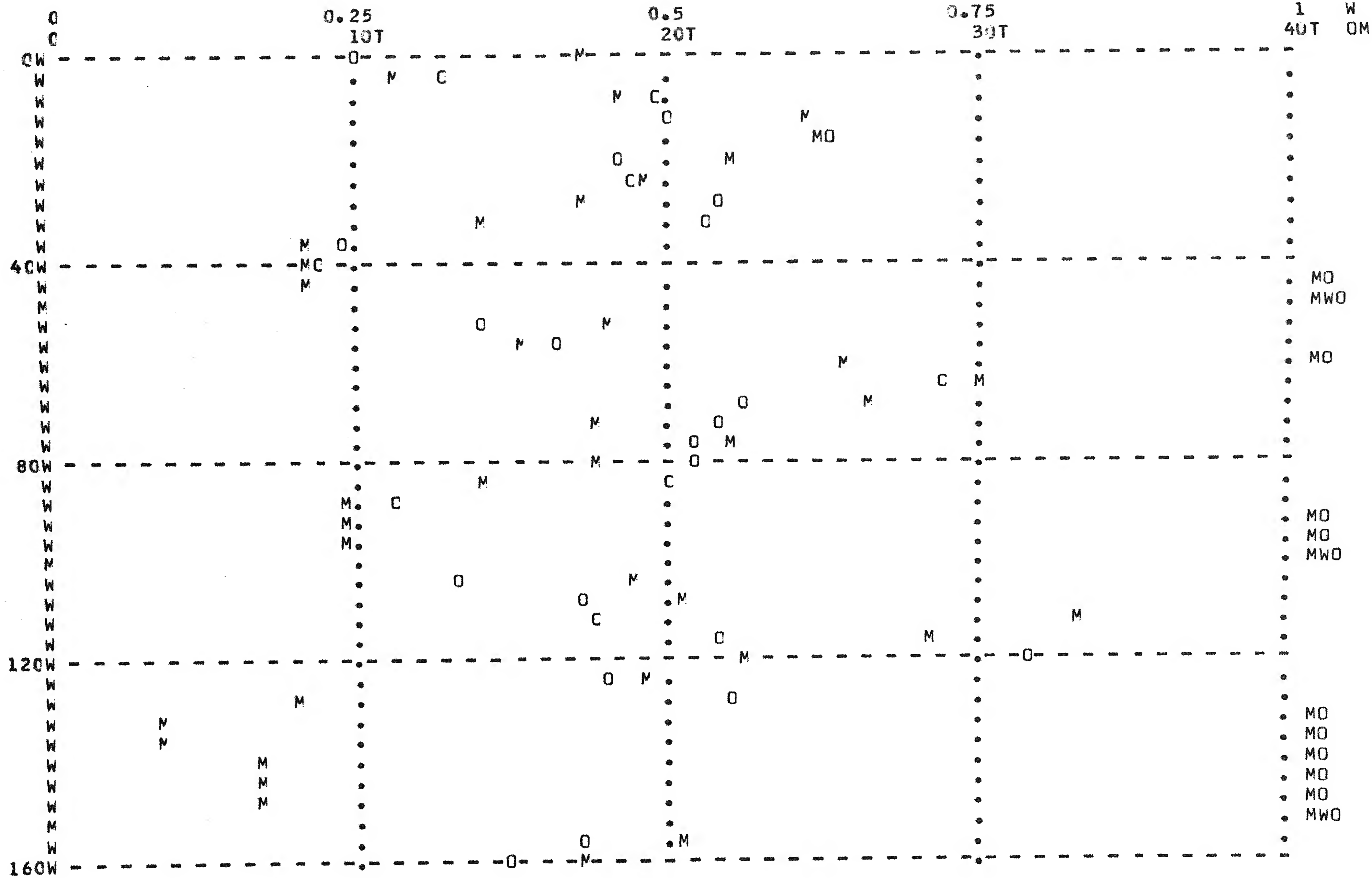


Fig. 21

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

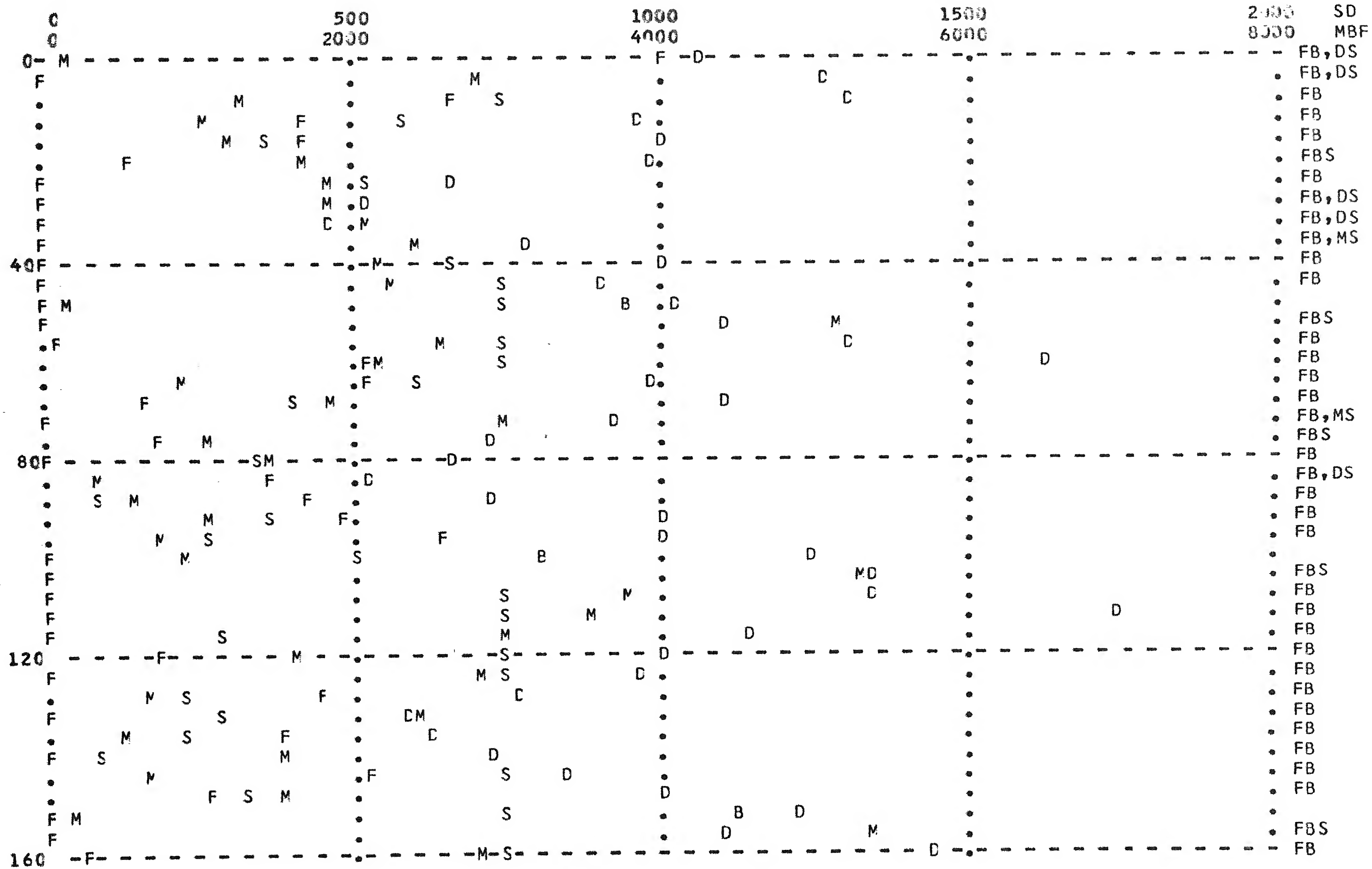


Fig. 22

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

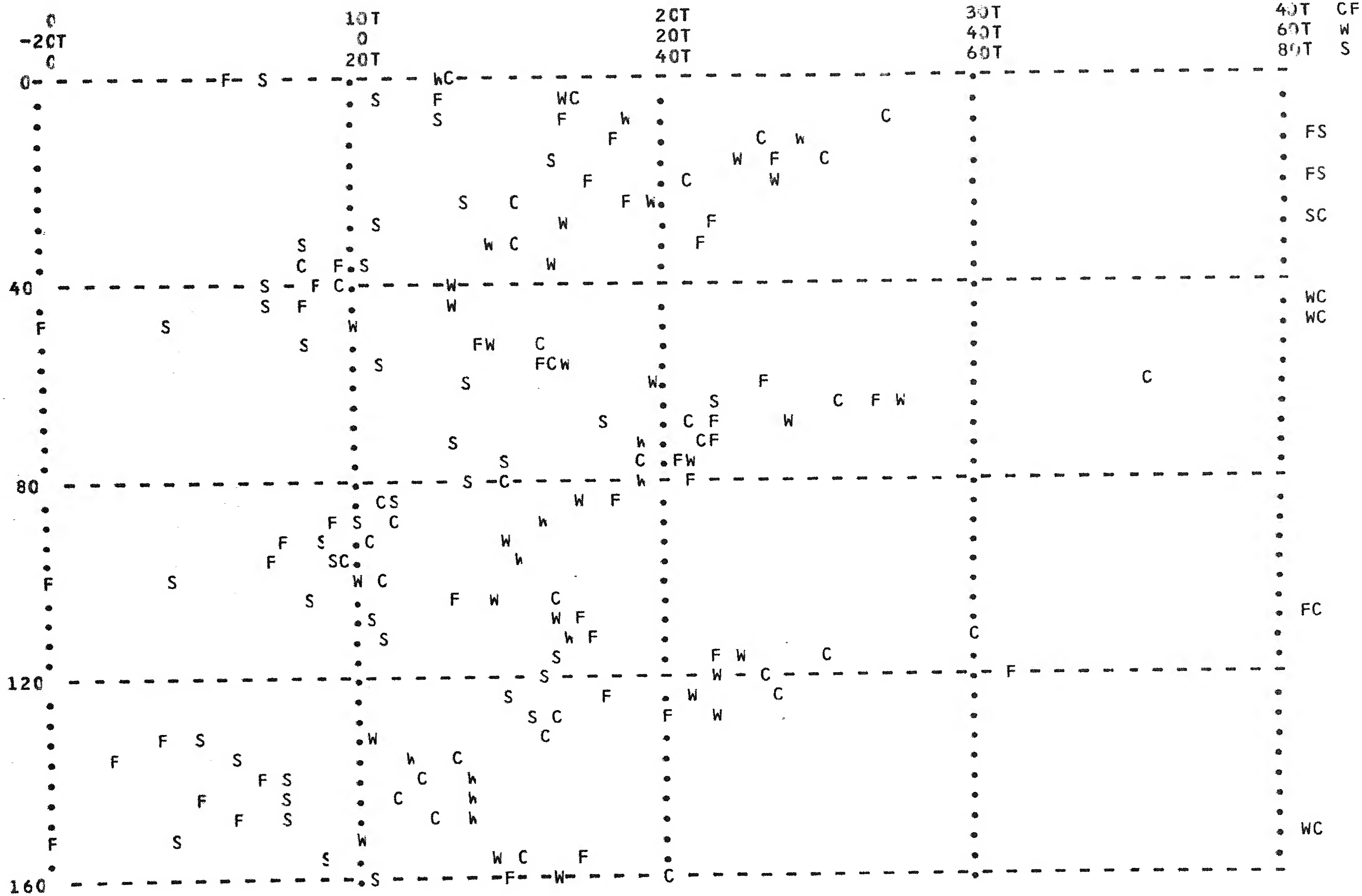


Fig. 23

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

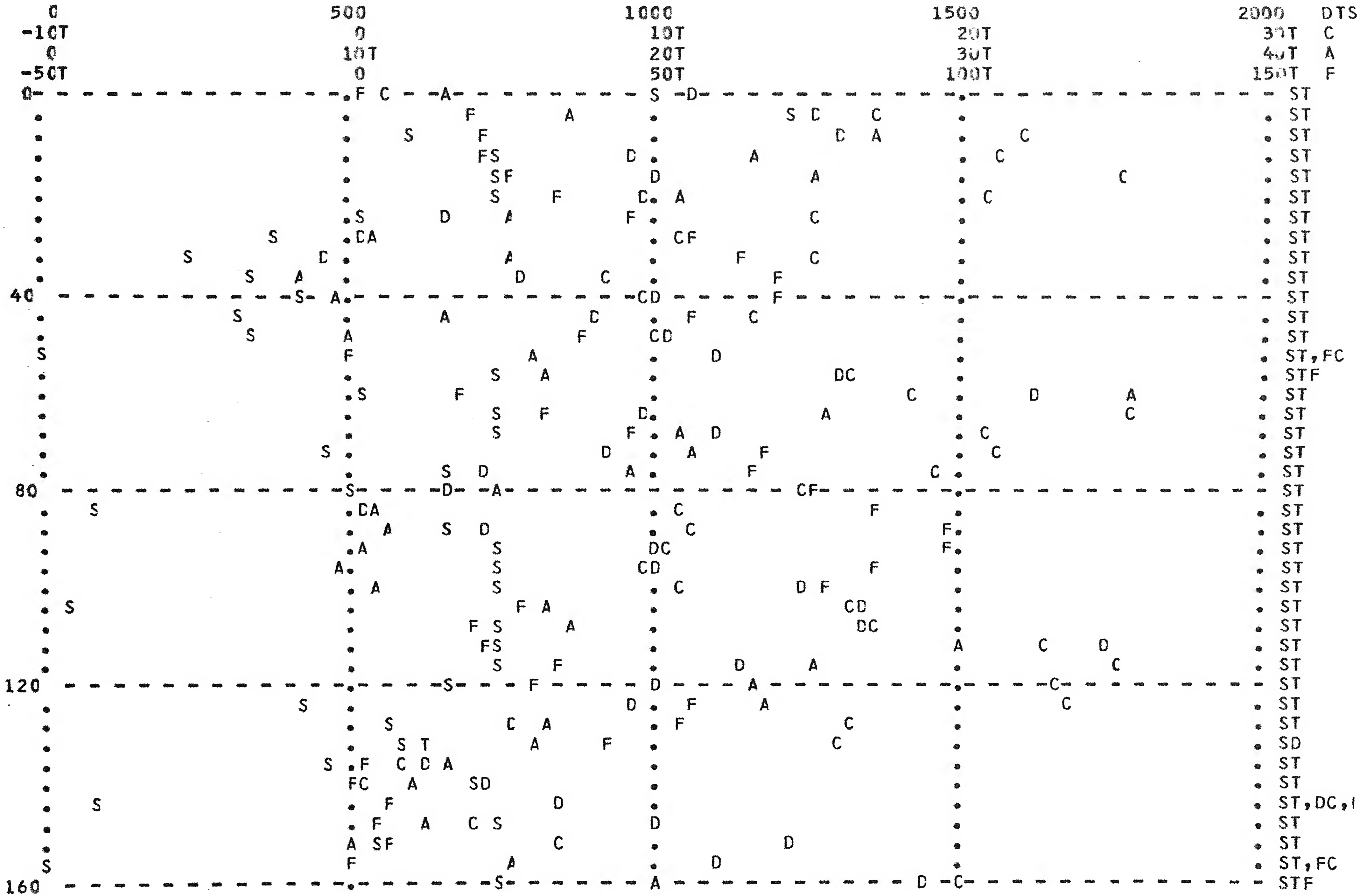


Fig. 24

BACK LOGS ARE NCT MET

	BCMI
SNK135	.MI
DECK01	1.MI

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPROI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.0 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.800	2.07	-1.444
52.00	900.0 786.48	12.444 14.713	175.6 900.0	0. 186.92	0. 3594.5	1052.3 163.64	505.34	210.36	124.48	5000.0	28.600	150.40	27.090
104.00	1007.2 830.20	13.214 15.531	586.8 1052.3	0. 197.41	0. 3796.3	1109.1 183.12	589.29	259.79	127.24	5000.0	28.600	182.91	25.403
156.00	737.7 748.75	12.342 13.931	1031.4 1109.1	0. 79.89	0. 1536.3	1154.2 134.13	581.74	248.34	133.39	5000.0	28.600	178.40	31.702

TABLE-5

PL=P, PLCTR=L, PLFF=F, PLAS=S

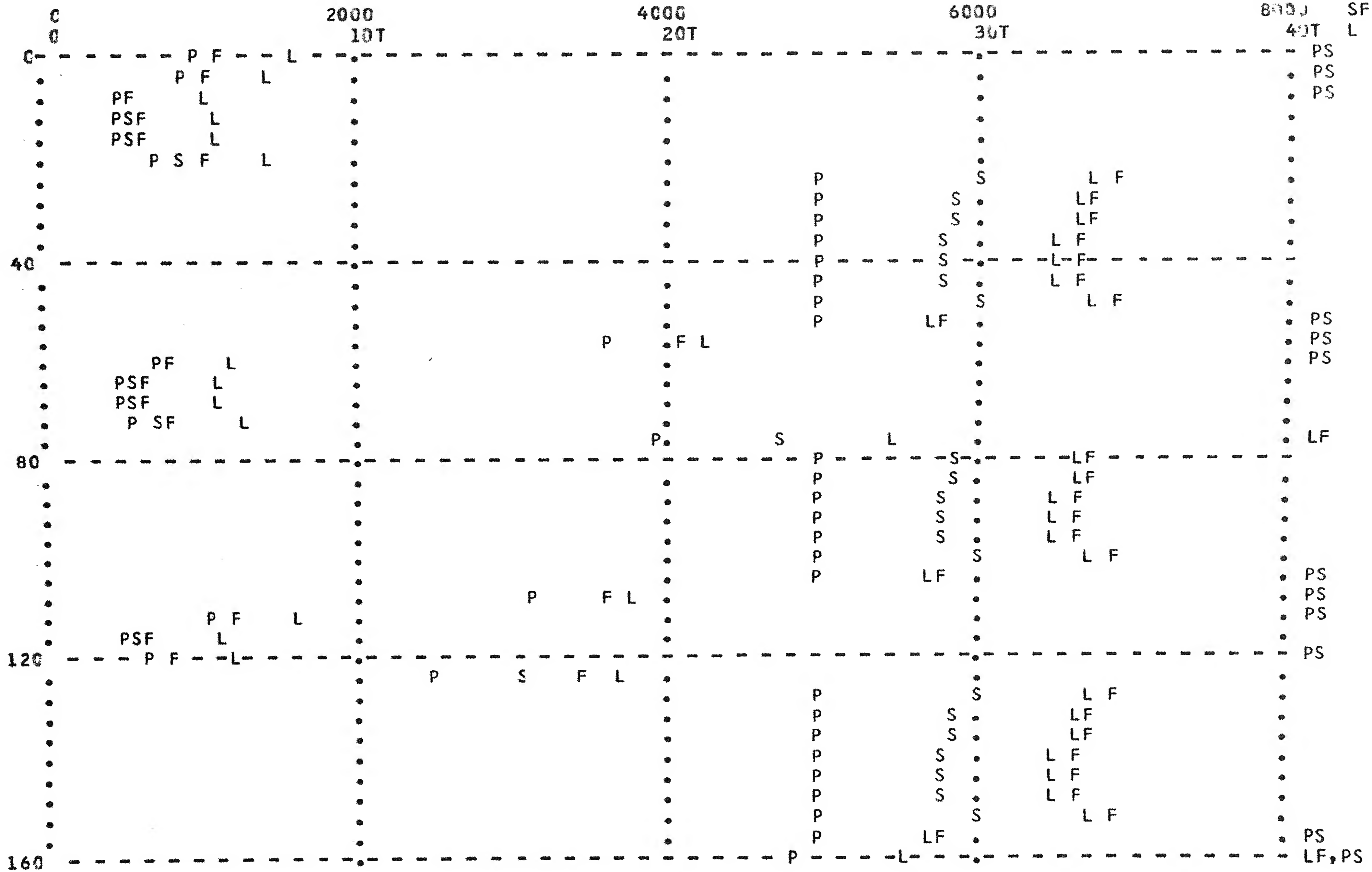


Fig. 25

PAGE 185 SNK135

P=P, H=H, D=D, S=S, I=I

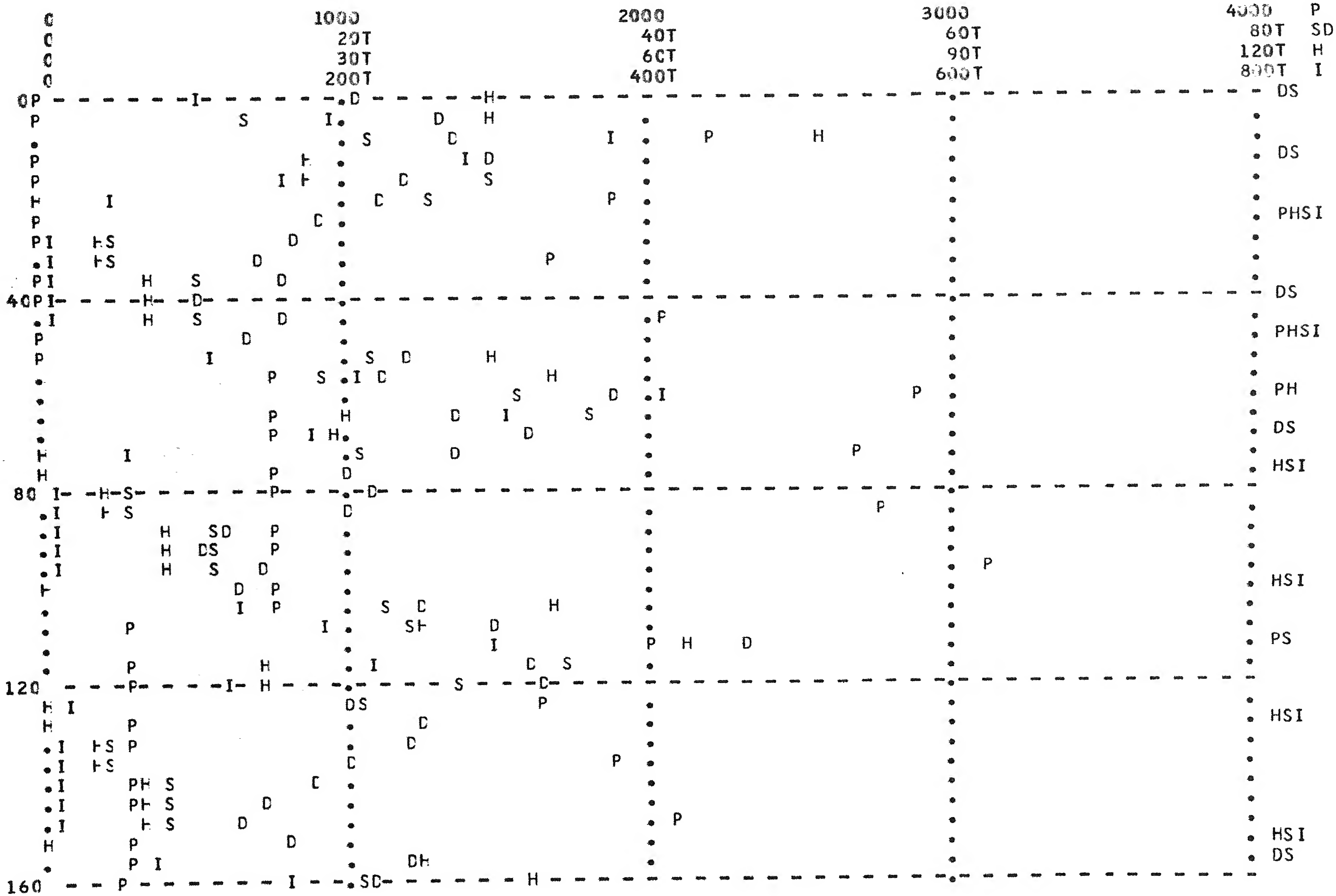


Fig. 26

MCST=M, MWCS=W, SOR=O

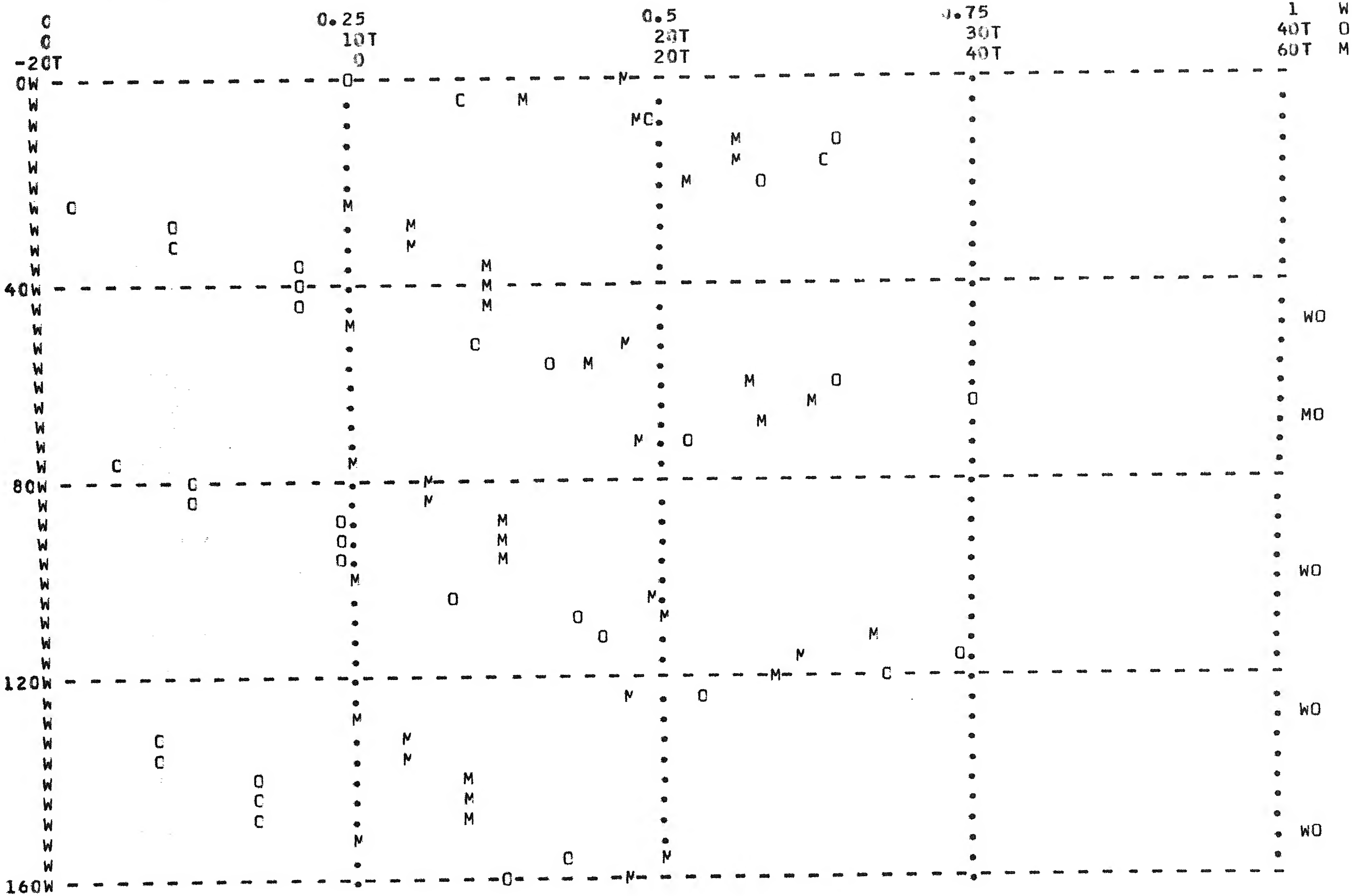


Fig. 27

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

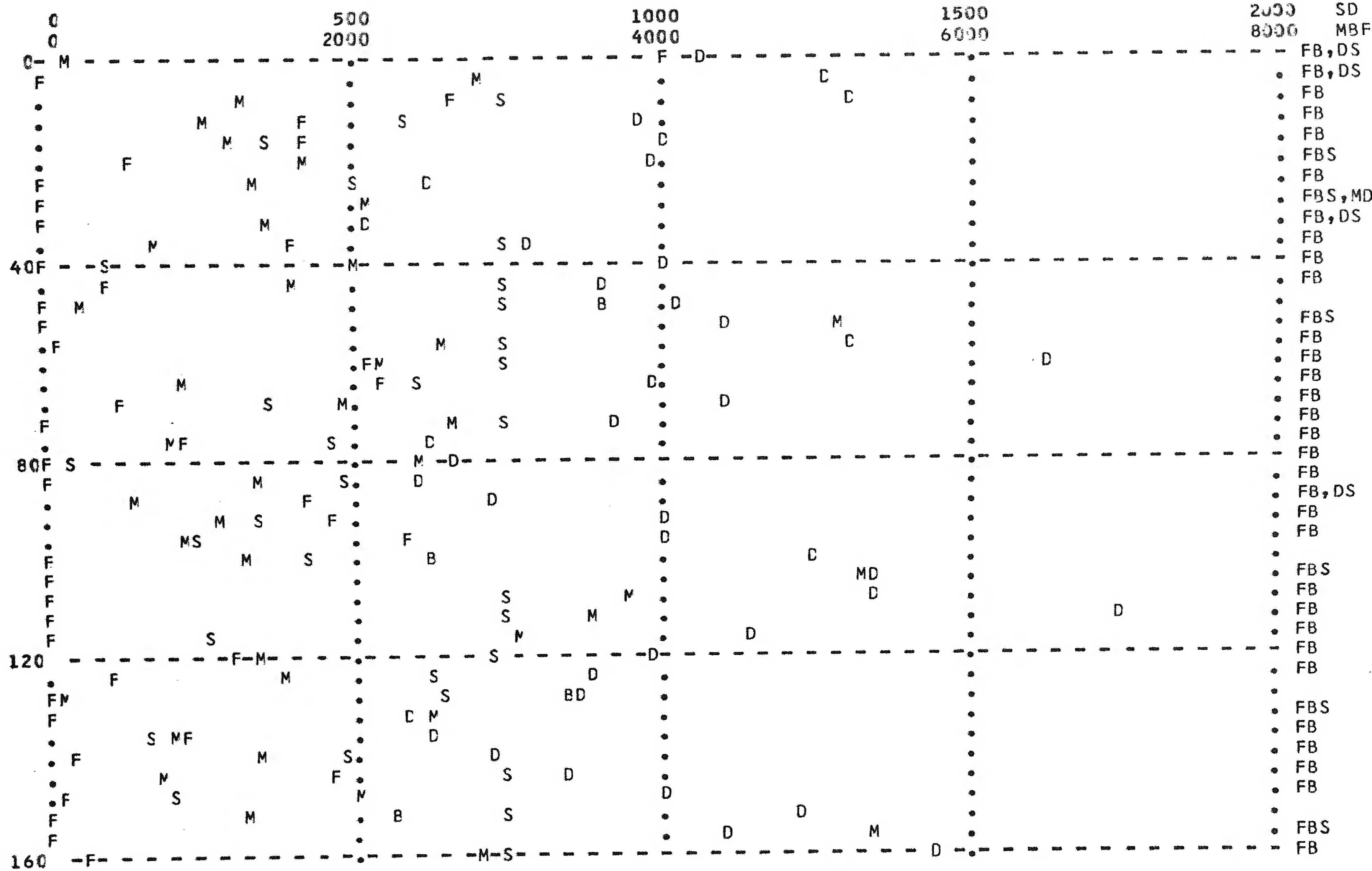


Fig. 28

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

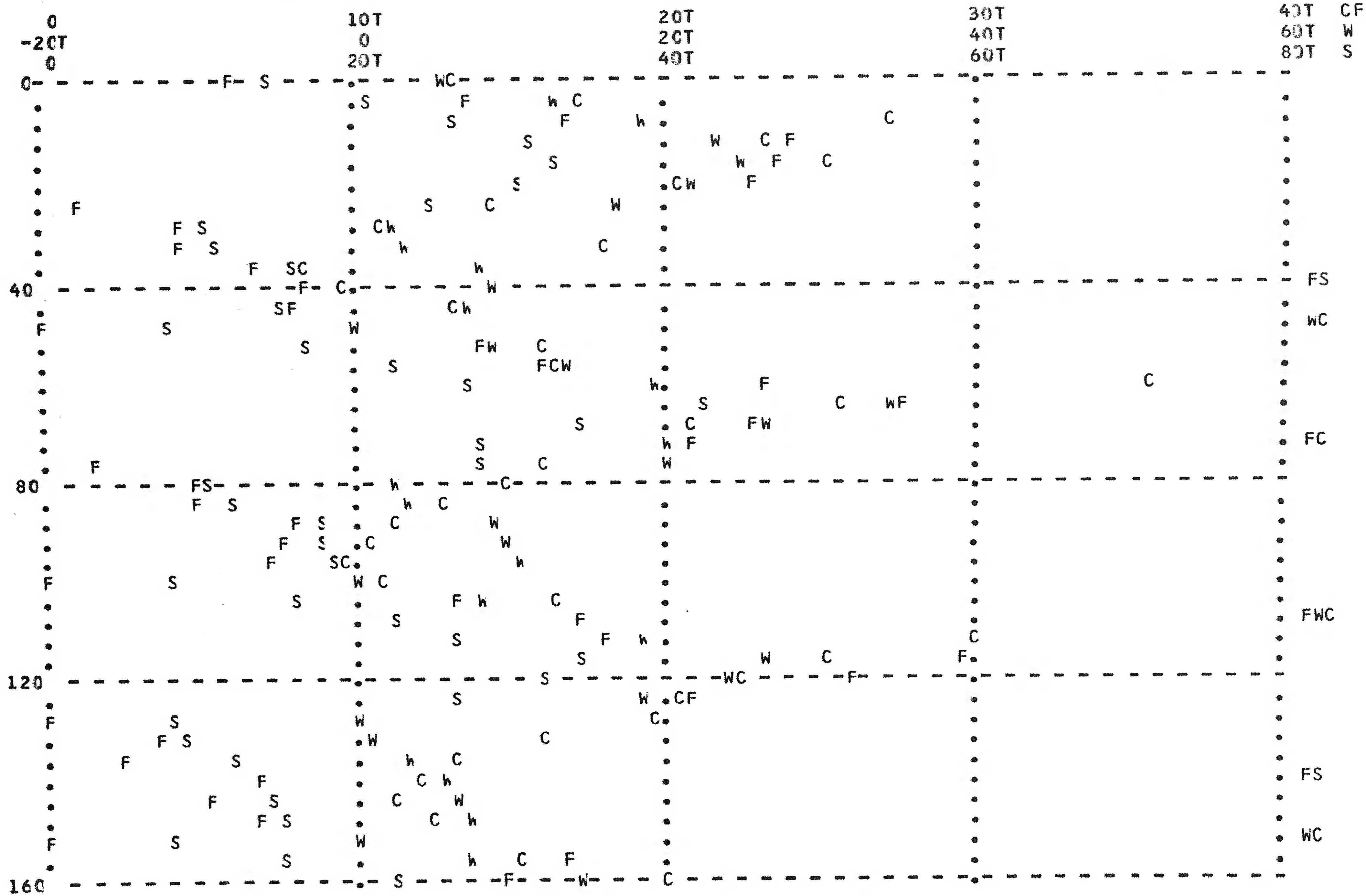


Fig. 29

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CCFF=A

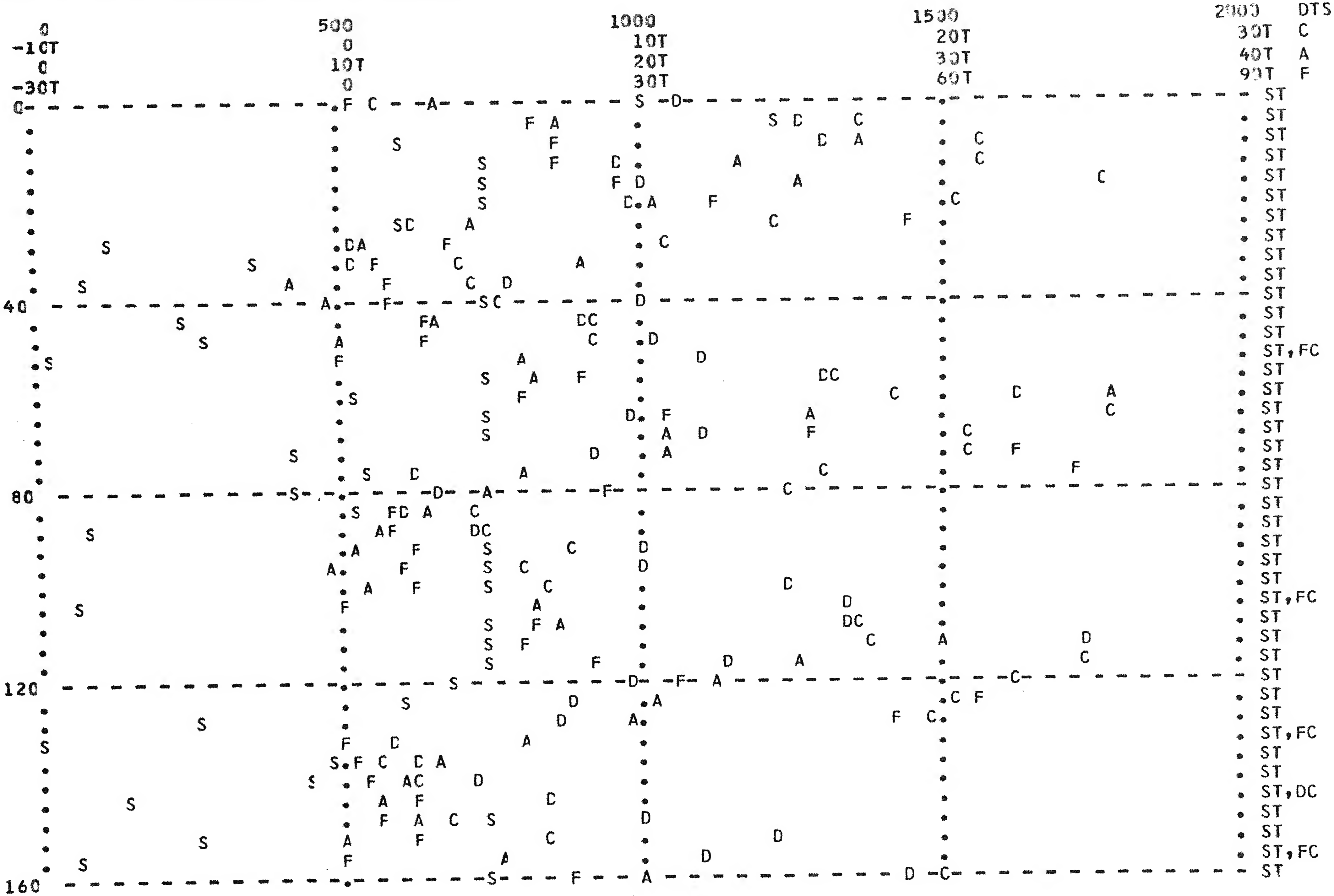


Fig. 30

DEMAND DOES NOT EFFECT PLANTING RATE

```
          DEP
SNK165     .EP
DECK01    5.EP
```

TIME	TACAH	ACSI	ASOB	TMWCS	AMWCS	TDLY*1	TPRCI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
	TSGCS	ASGCS	TDLY*2	TFWG	AFWG	THCI							
E+00	E+03	E+03	E+03	E+00	E+00	E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
	E+03	E+03	E+03	E+03	E+00	E+03							
.00	900.0	.000	.0	0.	0.	900.0	.00	.14	1.97	1000.0	7.600	2.07	-1.444
	20.66	.000	900.0	.00	.0	190.91							
52.00	900.0	12.183	175.3	0.	0.	1052.3	504.08	209.14	124.48	5000.0	28.600	150.40	27.057
	786.48	14.713	900.0	186.92	3594.5	163.64							
104.00	1007.2	13.068	586.7	0.	0.	1109.1	589.28	259.79	127.24	5000.0	28.600	182.91	25.393
	830.20	15.531	1052.3	197.41	3796.3	183.12							
156.00	737.7	11.690	1030.7	0.	0.	1154.2	578.98	245.04	133.39	5000.0	28.600	178.40	31.250
	748.75	13.931	1109.1	79.89	1536.3	134.13							

TABLE-6

PAGE 200 SKK165

PL=P, PLCTR=L, PLFF=F, PLAS=S

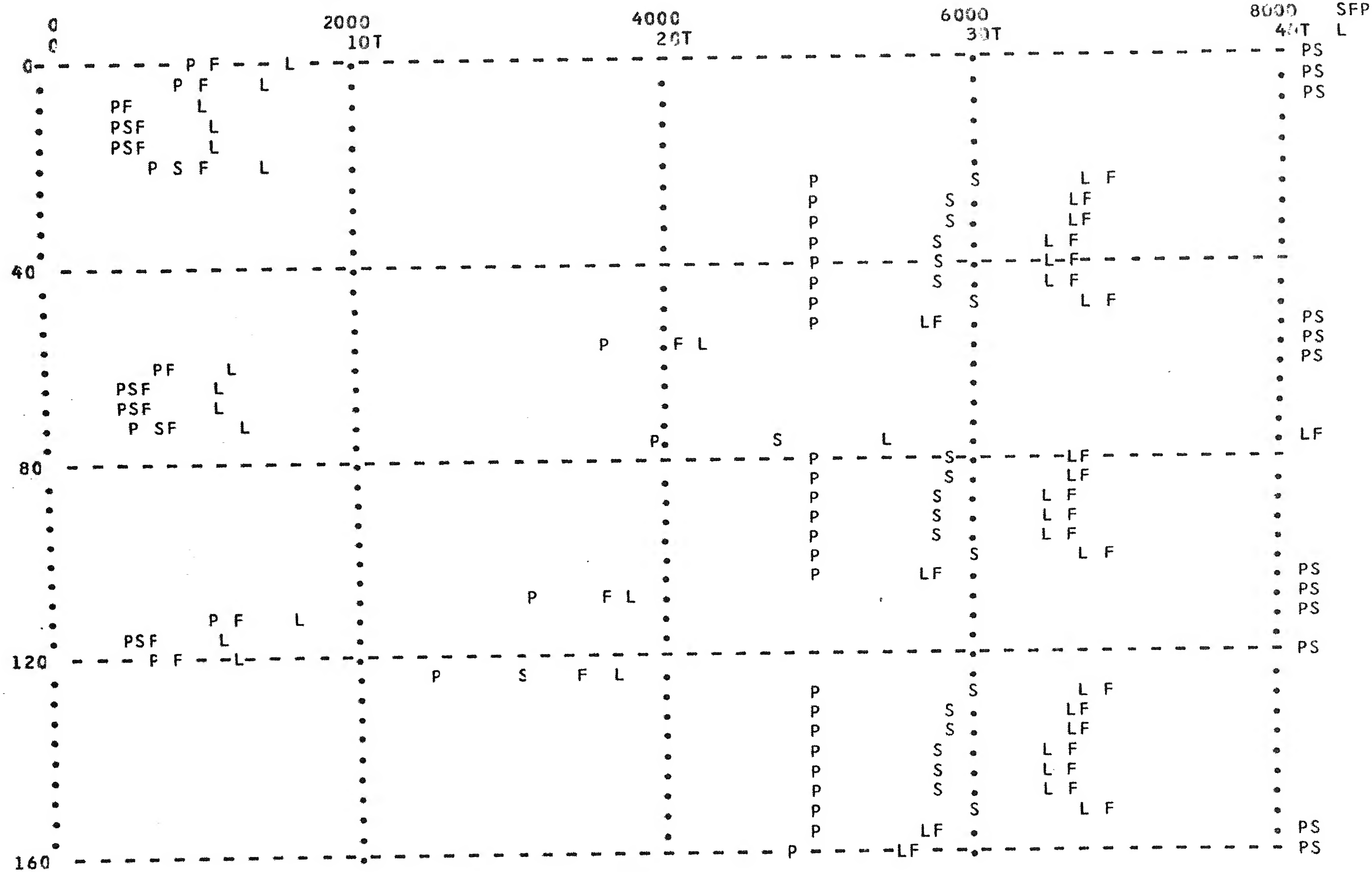


Fig. 31

P=P, H=H, D=D, S=S, I=I

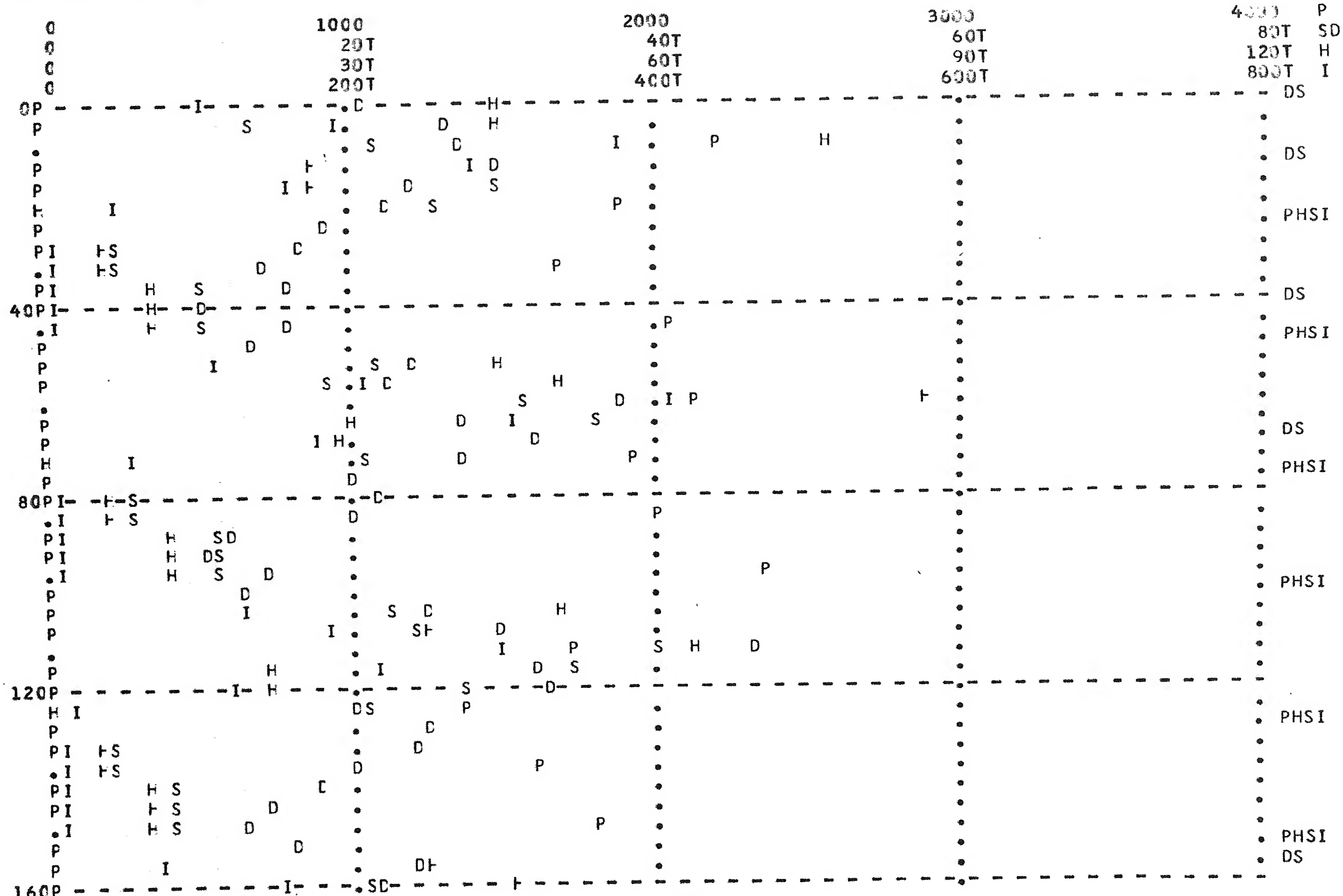


Fig. 32

PAGE 202 SNK165

MCST=M, MWCS=W, SOR=C

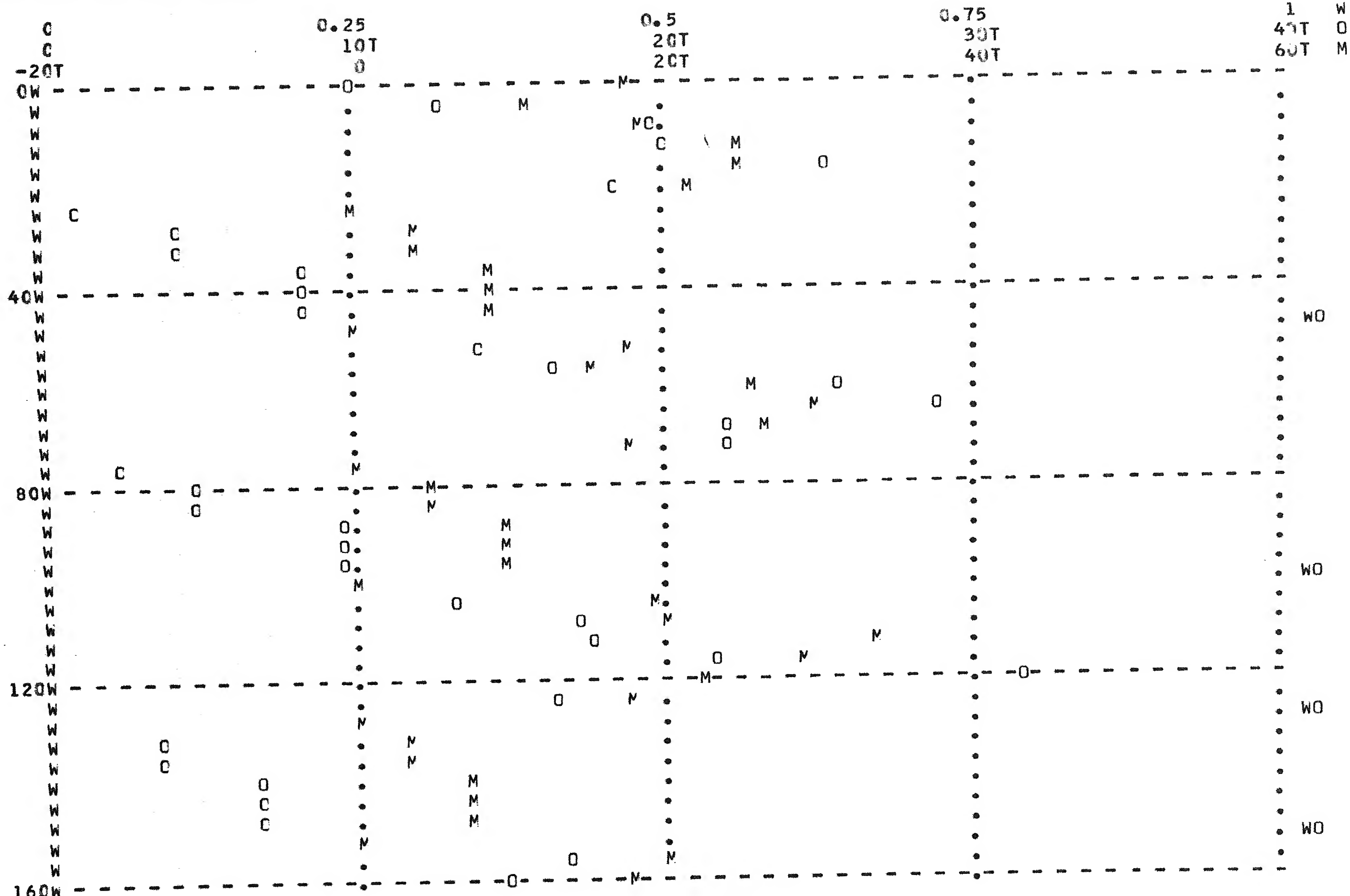


Fig. 33

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

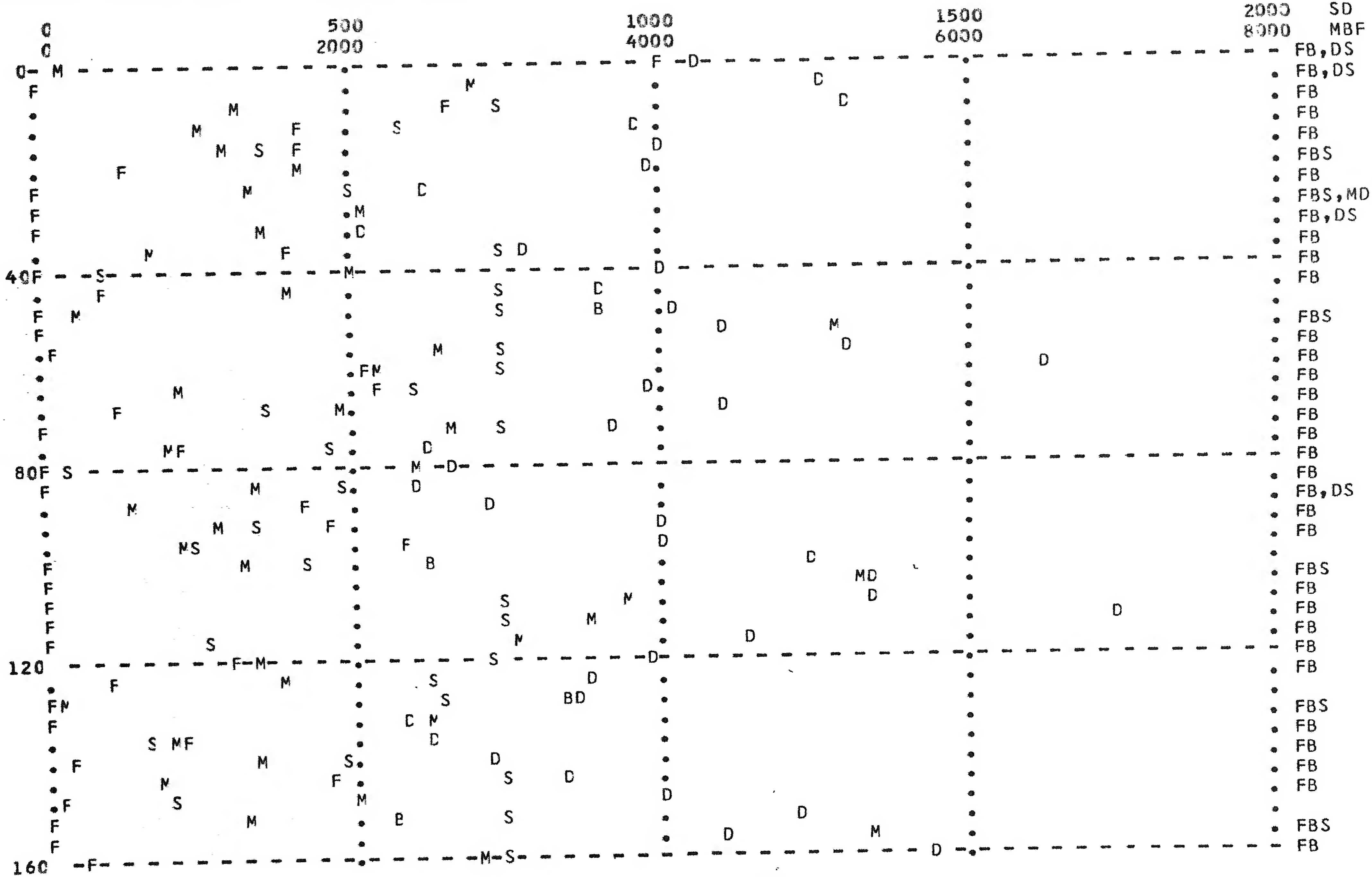


Fig 34

PAGE 204   SNK165

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

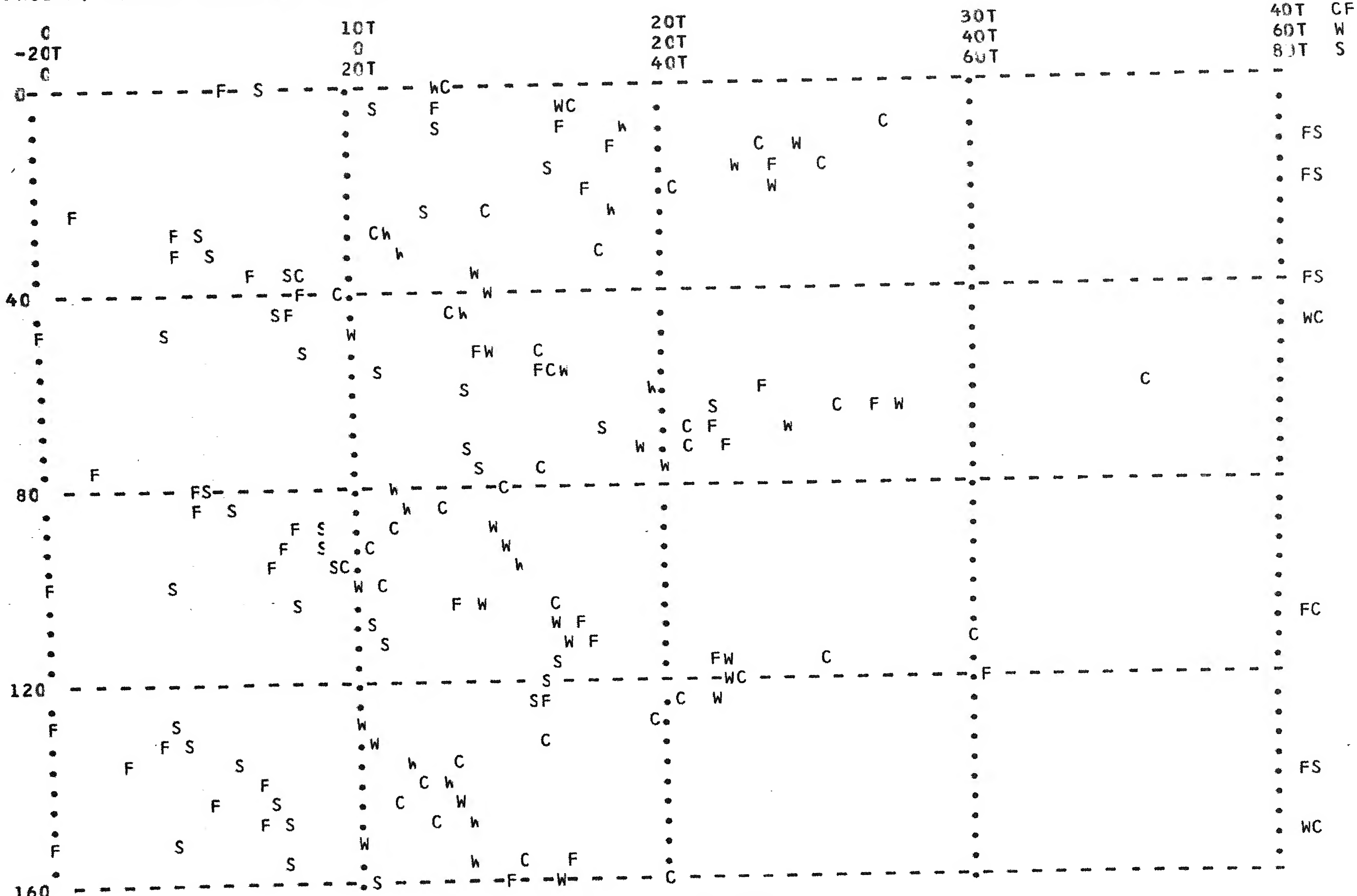


Fig 35

SRRS=S, TRS=T, CJTFR=D, RSSF=F, RSRC=C, CCFF=A

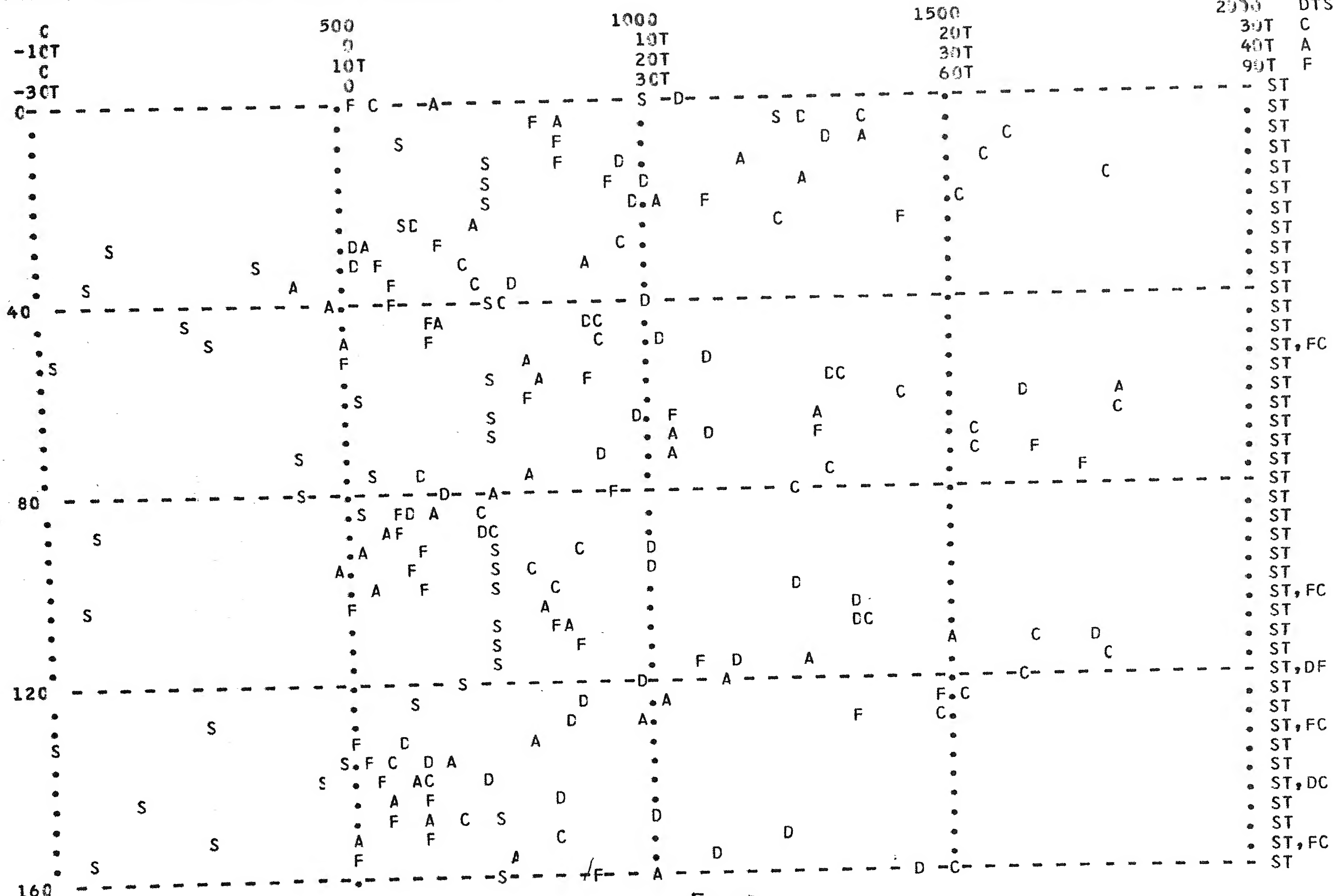


Fig. 36

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TDLY*2	TMWCS TFWG	AMWCS AFWG	TDLY*1 THCI	TPRCI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.00 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.600	2.07	-1.444
52.00	900.0 779.19	12.099 14.594	170.16 900.0	0. 190.78	0. 3668.8	1029.3 163.64	502.40	206.59	127.53	5000.0	28.600	148.03	26.880
104.00	1007.2 791.27	12.495 14.826	553.59 1029.3	0. 234.06	0. 4501.1	1031.5 183.12	558.14	244.39	121.49	5000.0	28.600	172.83	24.687
156.00	737.7 706.72	11.080 13.191	930.00 1031.5	0. 124.20	0. 2388.4	1019.8 134.13	514.58	215.02	123.58	5000.0	28.600	155.96	27.690

TABLE-7

PAGE 176 SAK124

PL=P, PLCTR=L, PLFF=F, PLAS=S

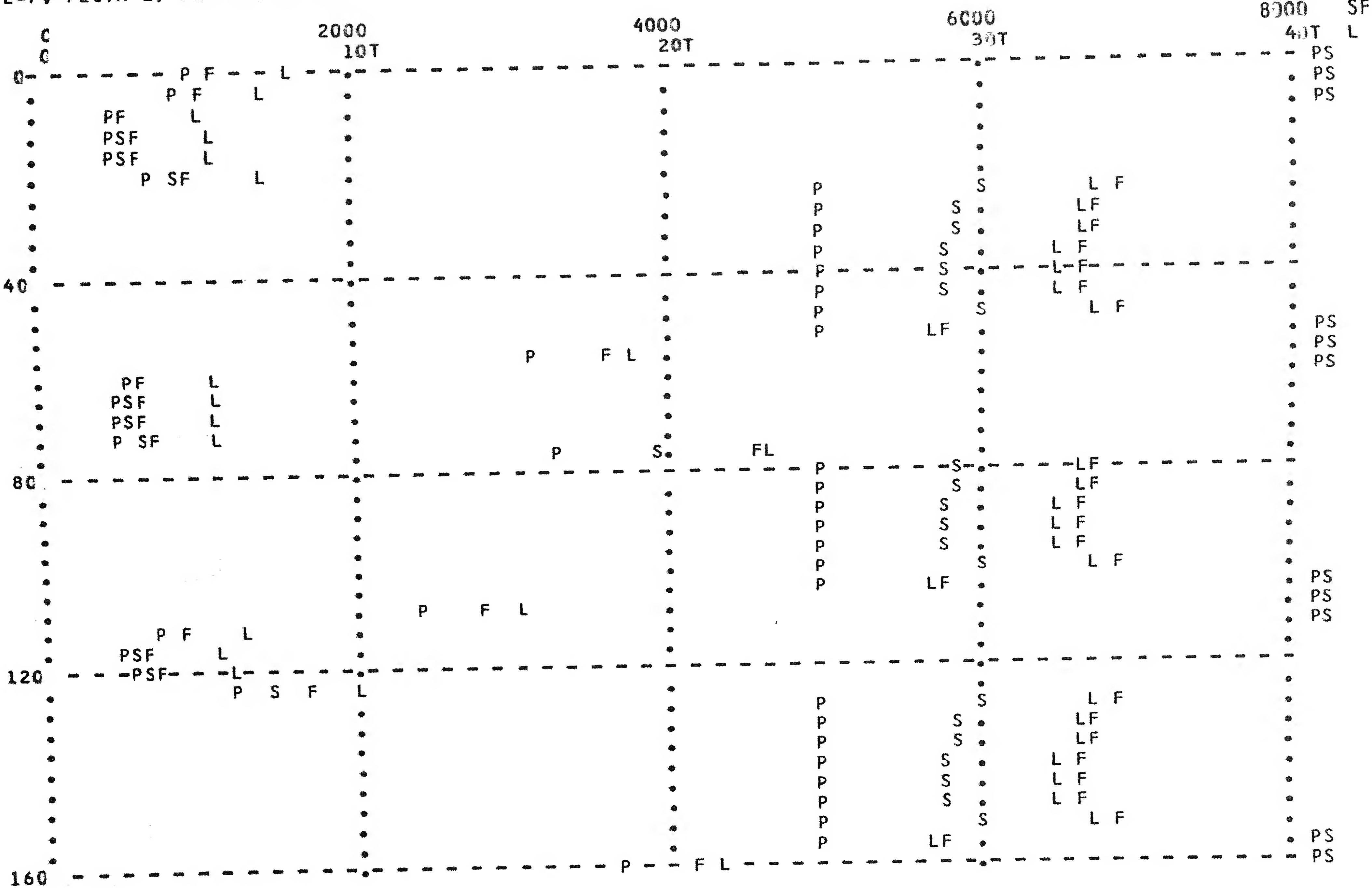


Fig. 37

P=P, H=H, D=C, S=S, I=I

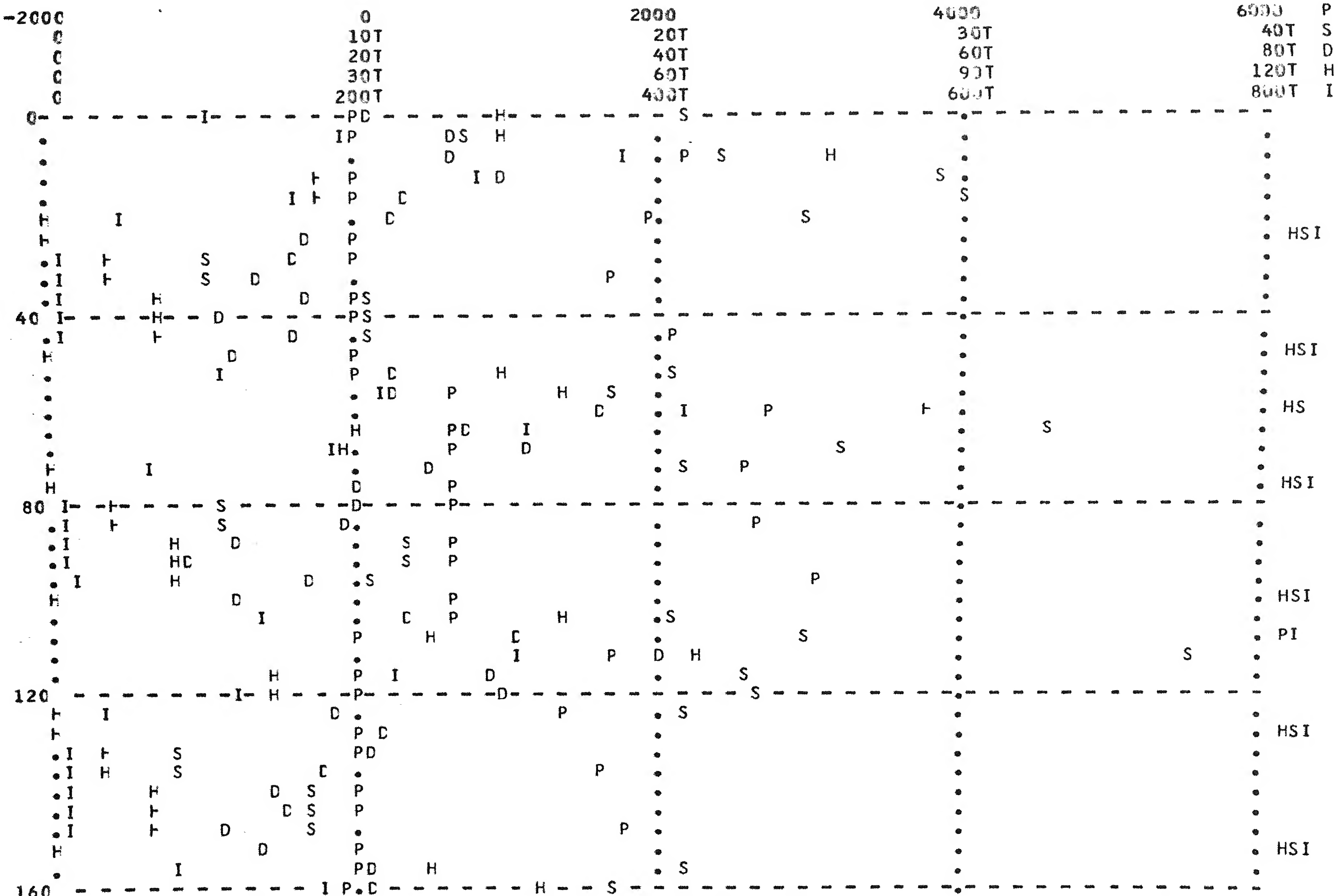


Fig. 3a

PAGE 178   SAK124

MCST=M, MWCS=W, SOR=O

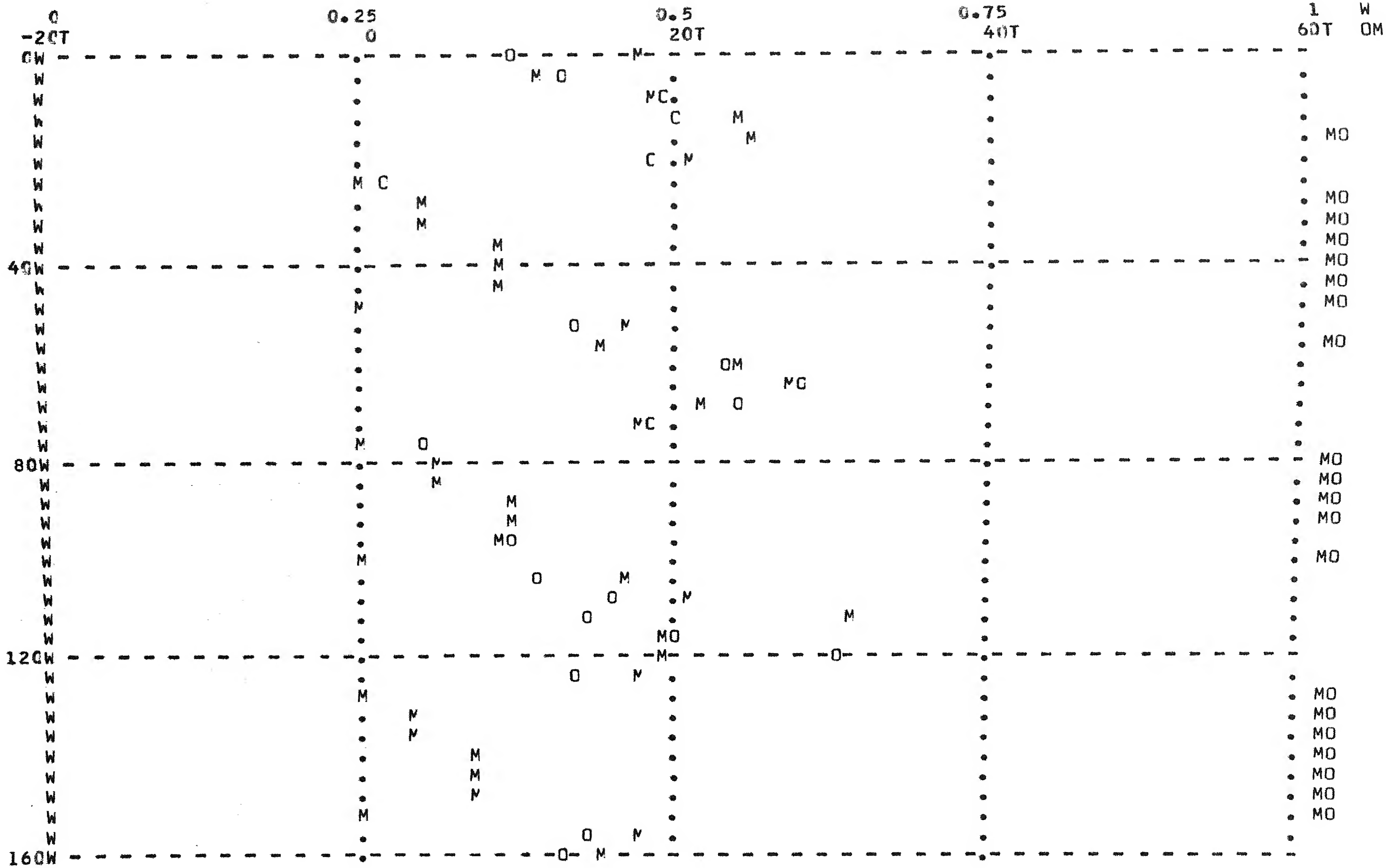


Fig. 39

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

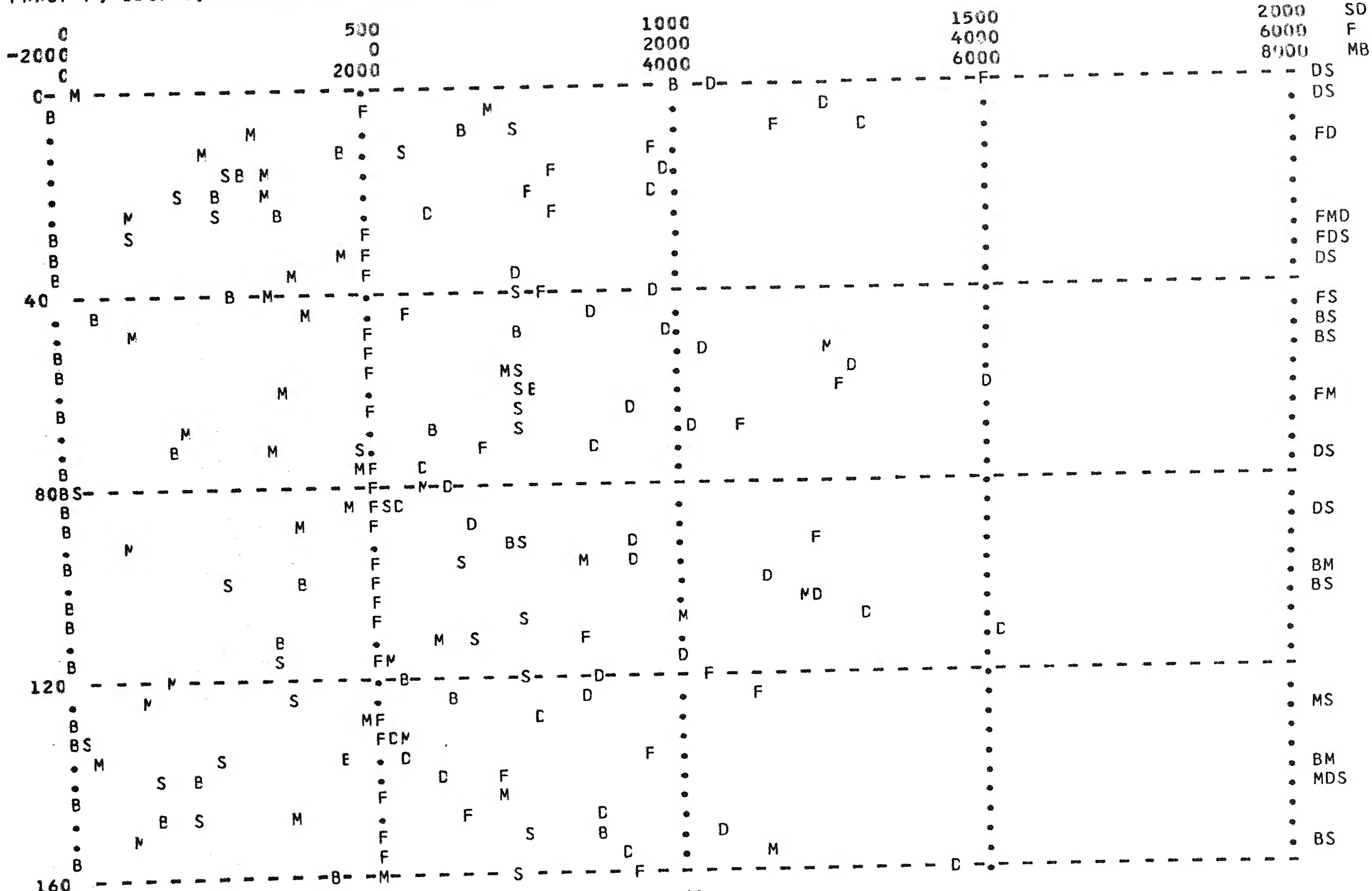


Fig. 40

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

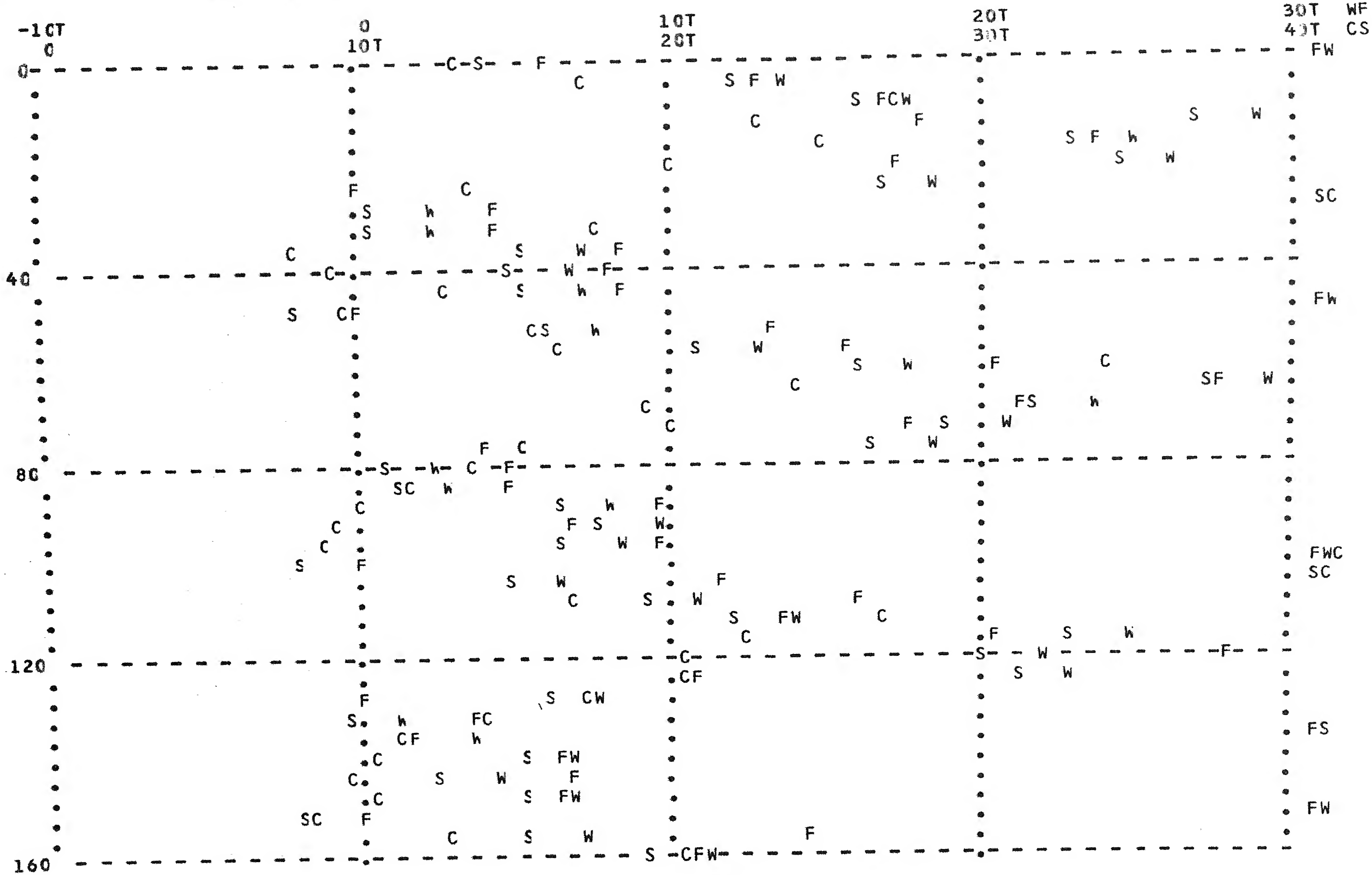


Fig. 41

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

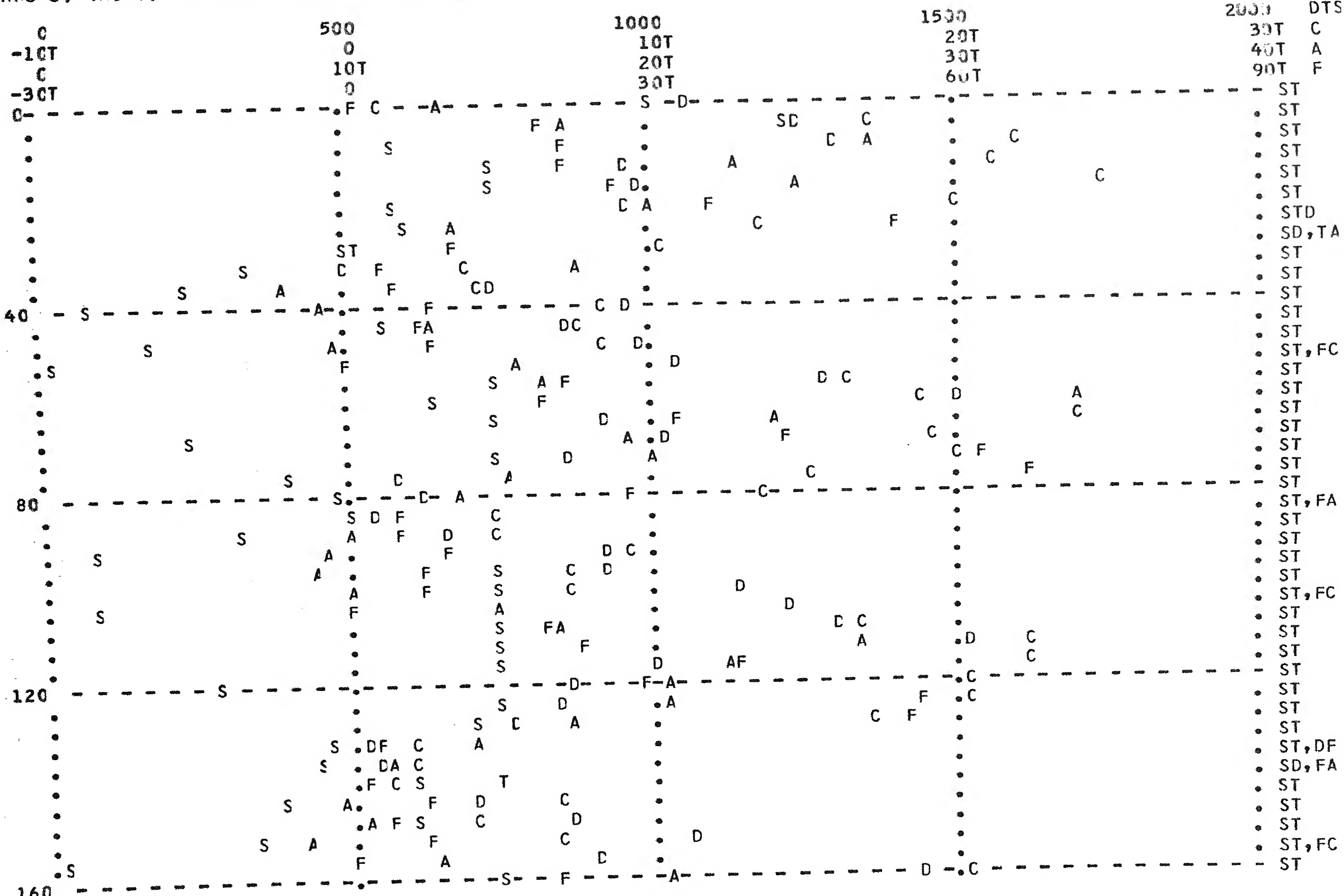


Fig. 42

TIME	TACAH TSGCS	ACSI ASGCS	ASOB TCLY*2	TMWCS TFWG	AMWCS AFWG	TCLY*1 THCI	TPROI	PRFF	PRJF	PL	PLCTR	PROG	PRCS
E+00	E+03 E+03	E+03 E+03	E+03 E+03	E+00 E+03	E+00 E+00	E+03 E+03	E+06	E+06	E+06	E+00	E+03	E+06	E+06
.00	900.0 20.66	.000 .000	.00 900.0	0. .00	0. .0	900.0 190.91	.00	.14	1.97	1000.0	7.600	2.07	-1.44
52.00	900.0 779.19	12.099 14.594	170.16 900.0	0. 190.78	0. 3668.8	1029.3 163.64	502.40	206.59	127.53	5000.0	28.600	148.03	26.88
104.00	1007.2 833.99	13.107 15.606	569.00 1029.3	0. 200.99	0. 3665.1	1107.2 183.12	587.16	255.45	131.14	5000.0	28.600	181.60	24.99
156.00	737.7 731.40	11.449 13.625	990.89 1107.2	0. 90.88	0. 1747.7	1093.2 134.13	568.68	234.65	142.67	5000.0	28.600	169.31	30.77

TABLE—8

PL=P, PLCTR=L, PLFF=F, PLAS=S

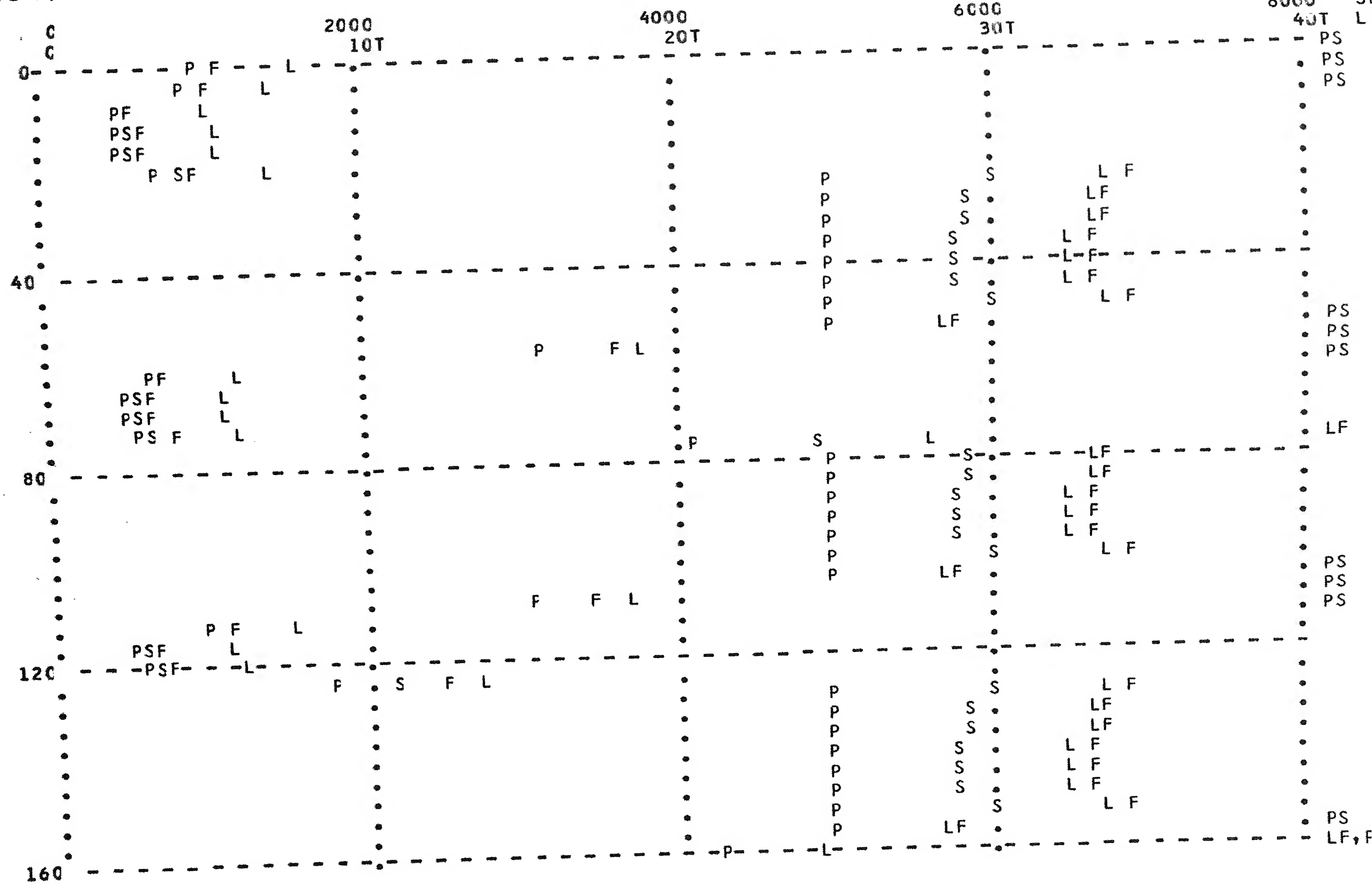


Fig. 43

PAGE 33 D12345

P=P, H=H, D=D, S=S, I=I

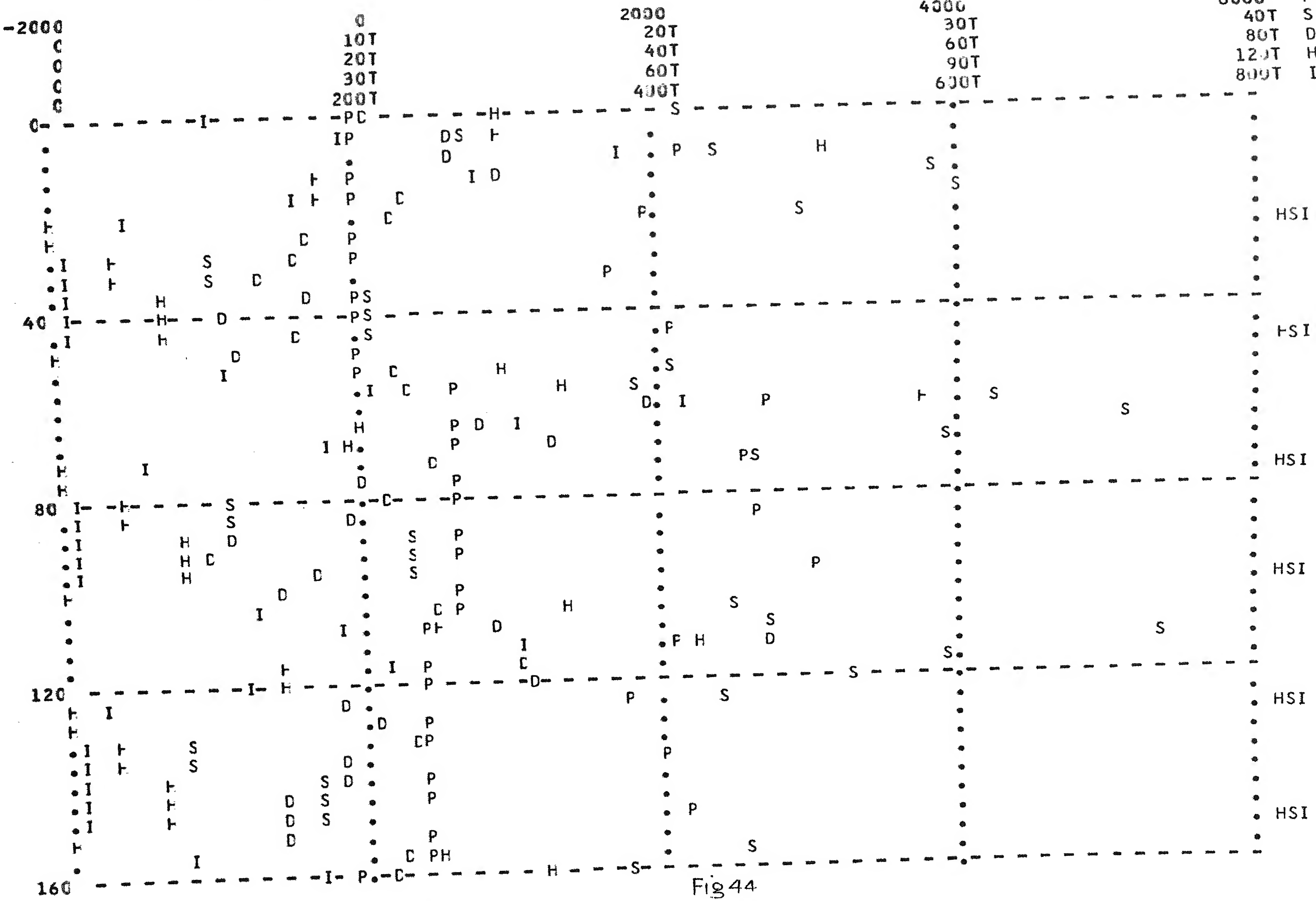


Fig 44

MCST=M, MWCS=W, SOR=C, SOE=B

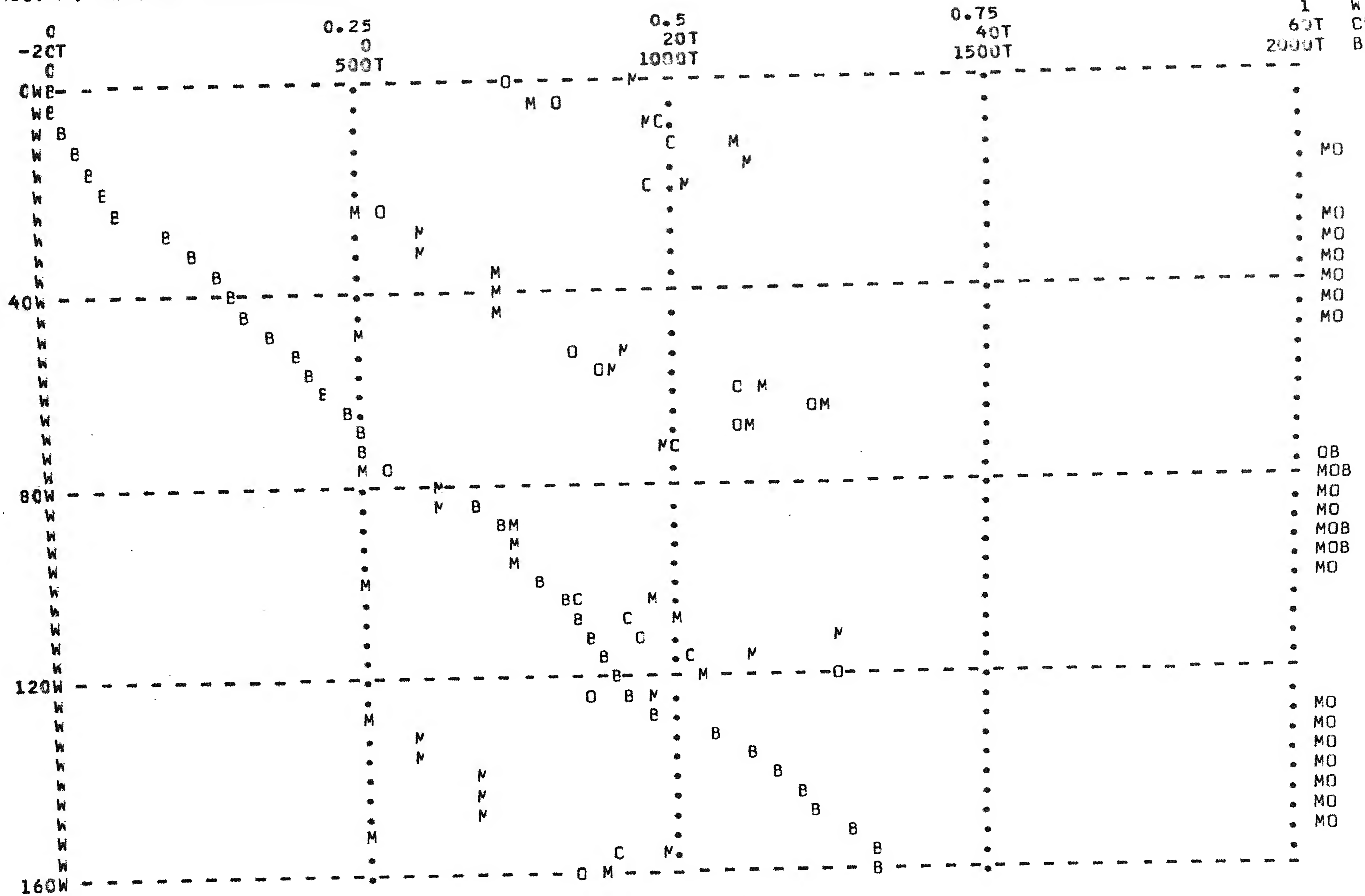


Fig. 45

MCST=M, MWCS=W, SOR=C, SOE=B

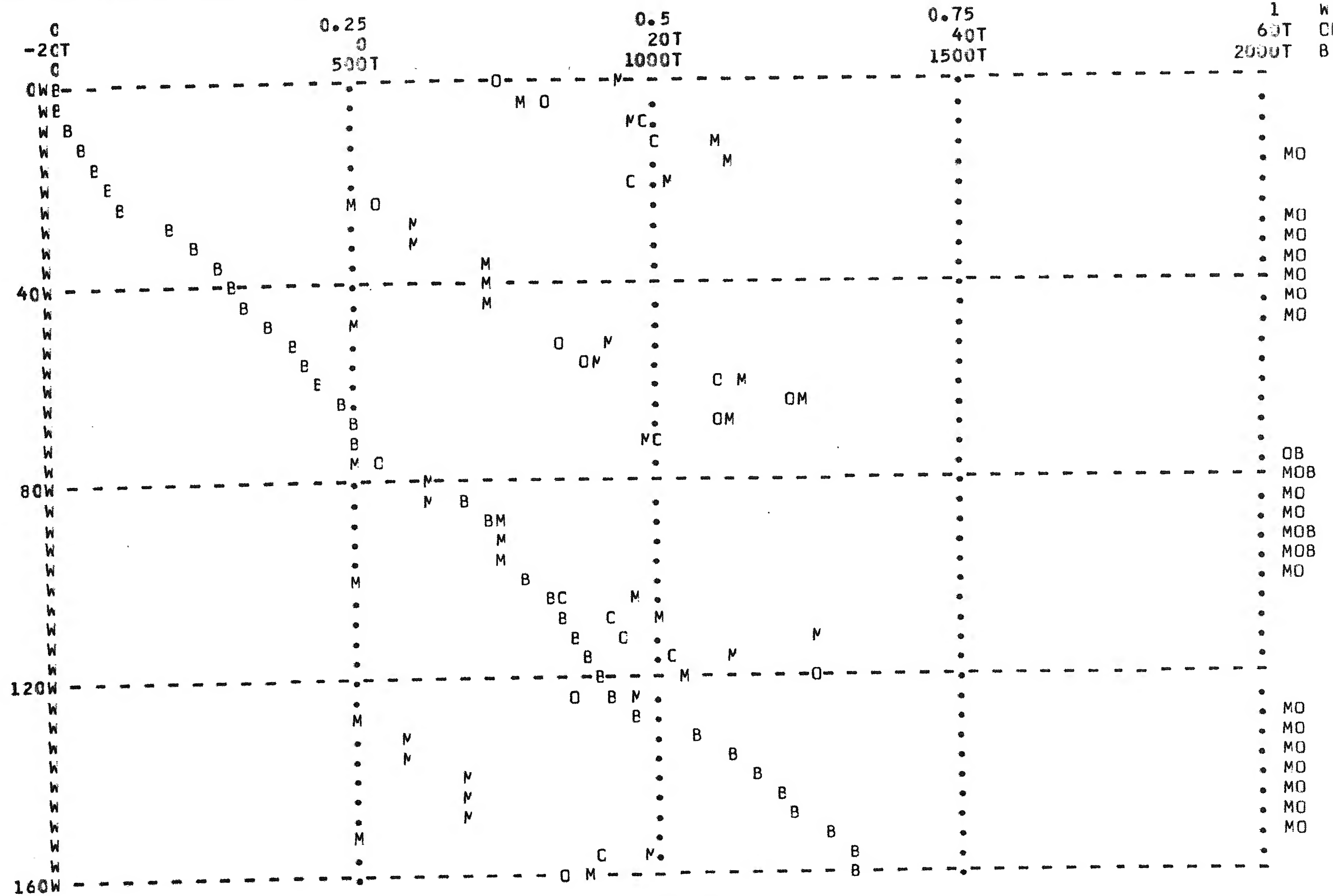


Fig. 45

FRRJF=F, BDJF=B, MSJF=M, CJTFR=C, SRRJF=S

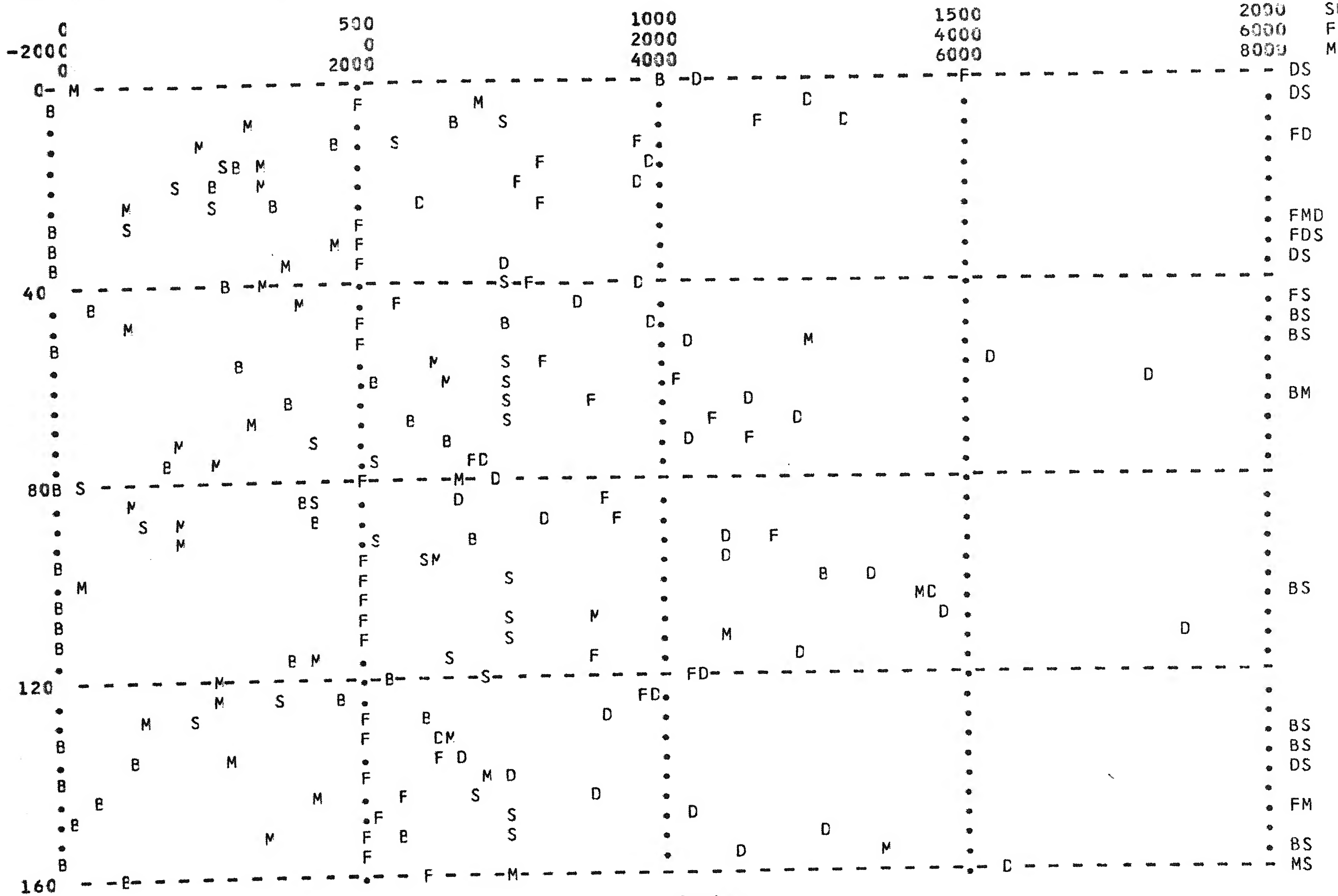


Fig. 46

FPRCS=F, FSCS=S, WSFFR=W, CDFF=C

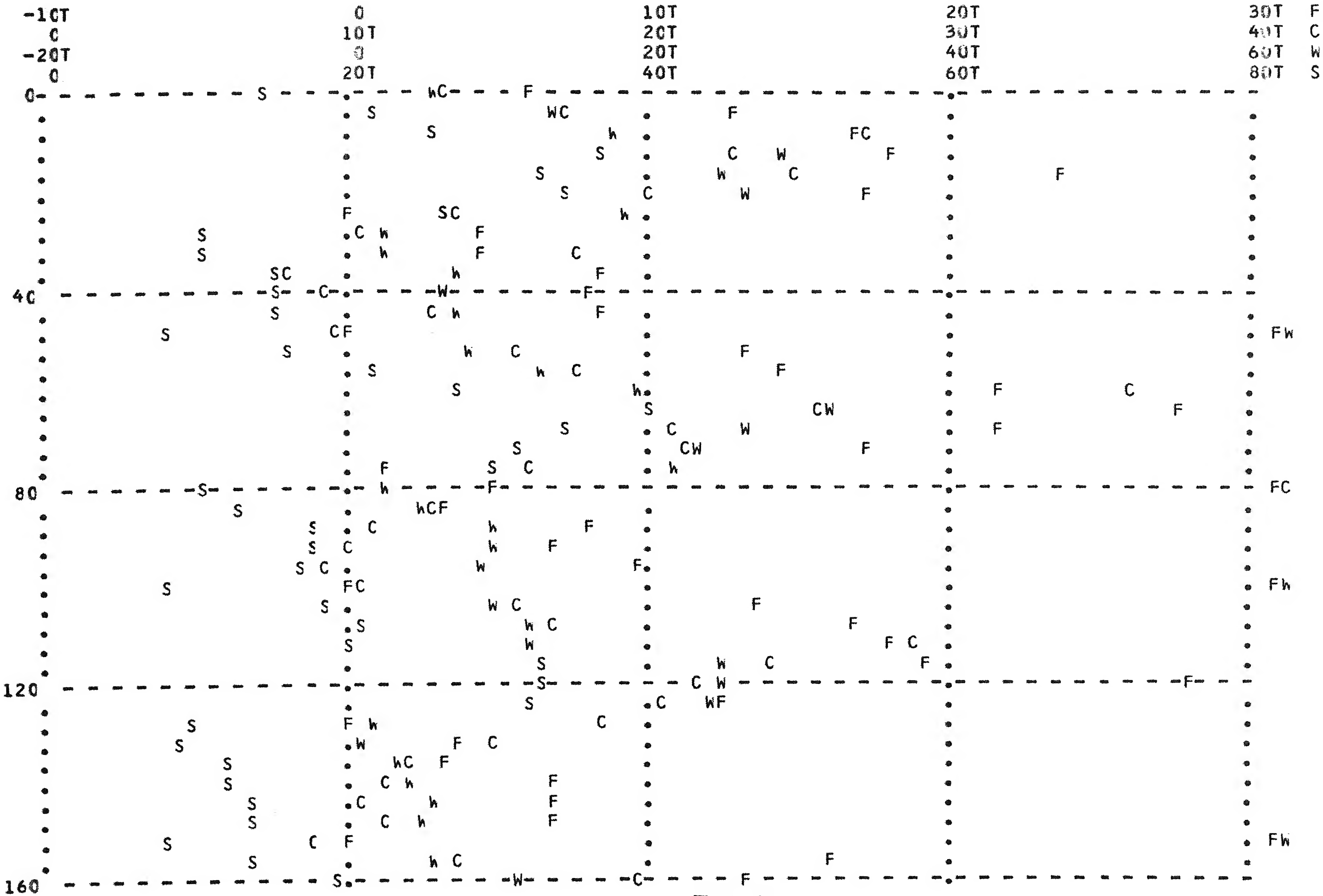


Fig. 47

SRRS=S, TRS=T, DJTFR=D, RSSF=F, RSRC=C, CDFF=A

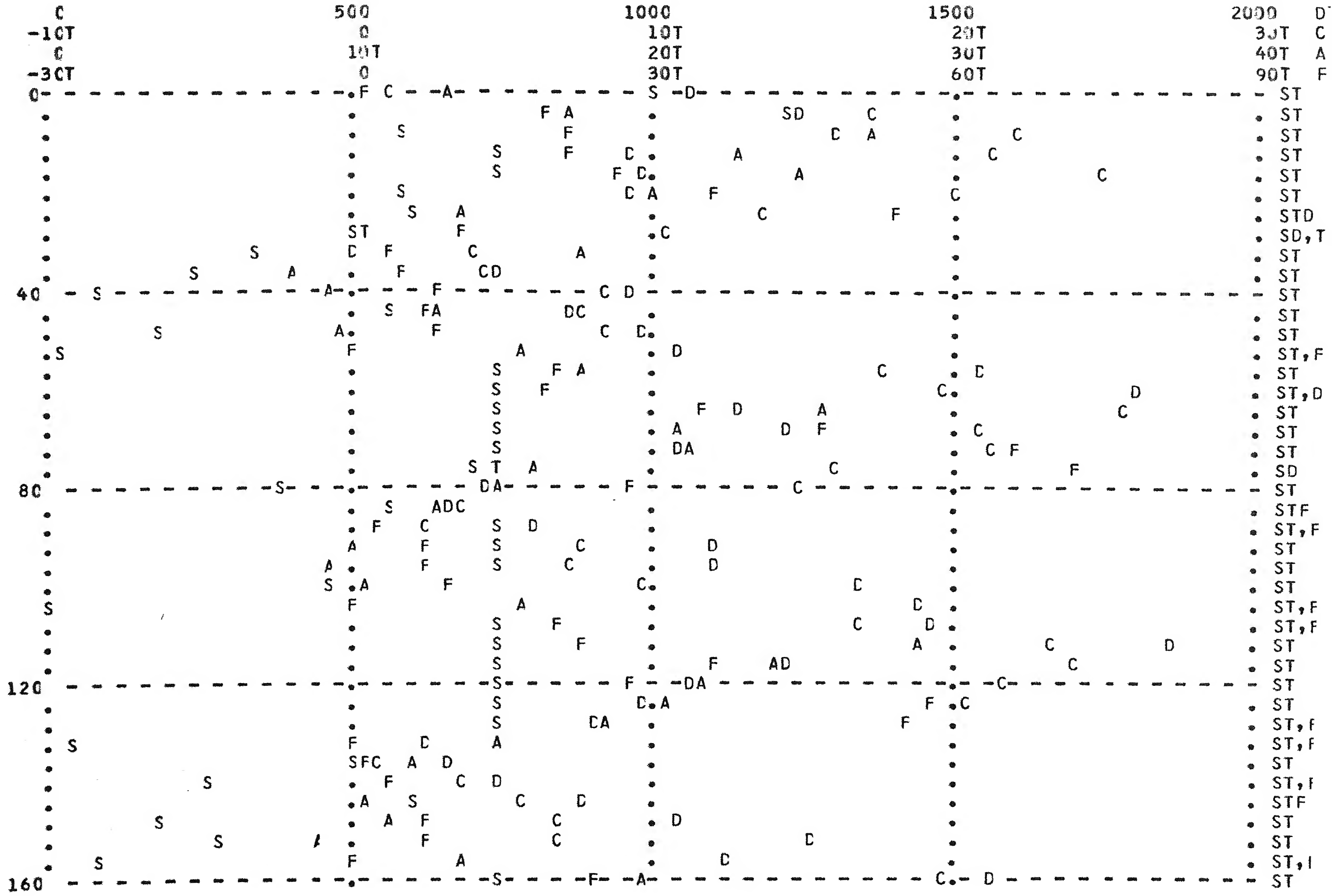


Fig. 48

APPENDIX D
COMPUTER PROGRAM LISTING

```
**************************************************************************
*SYSTEMS  BEHAVIOUR  OF A PERISHABLE  COMMODITY  INDUSTRY *
*-------                                                  *
*                     -AN  INDUSTRIAL  DYNAMICS  APPROACH *
*                                                         *
**************************************************************************
$EXECUTE          DYNAMO
*       MEG-208,DYN
RUN     DECK01
NOTE                                          ***********************************
NOTE    IN THE INITIAL RUN THE ASSUMPTIONS ARE-
NOTE    BACK ORDERS ARE MET FIRST
NOTE    DEMAND AFFECT PLANTING RATE
NOTE    TREND IN DEMAND WITH NO SUDDEN CHANGE
NOTE    THERE IS WASTAGE IN COLD STORAGE
NOTE                                          ***********************************
NOTE
NOTE      AGRICULTURE SECTOR
NOTE
NOTE    1 TON=1 METRIC TON =1000KG
NOTE                                          ***********************************
NOTE                                          TOTAL CROP
NOTE                                          ***********************************
                                                                          4-1-1
1L      TCROP.K=TCROP.J+(DT)(RFT.JK-ROTB.JK)
6N      TCROP=90000                                                       4-1-2
44R     RFT.KL=(P1*2.K)(PPI*1.K)/FDIC                                     4-1-3
35L     PPI=BOXCYC(13,4)
C       PPI*=0/0/1/0/0/1/0/0/1/0/0/1/                                     4-1-4
C       FDIC=16                                                           4-1-5
44R     ROTB.KL=(ROTB1.K)(PPI*1.K)/FDIC
20A     ROTB1.K=TACAH.JK/FP.K                                             4-1-6
7A      FP.K=30+FP1.K
33A     FP1.K=(10)NOISE
NOTE                                          PLANTING RATE
NOTE                                          ***********************************
                                                                          4-1-7
5R      P.KL=P3.K
14A     P3.K=ROTB.JK+(DEP)(CDFLY.K)                                       4-1-8
C       DEP=.005                                                          4-1-9
37B     P1=BOXLIN(7,52)
36N     P1=BOXLOAD(300,0,1)
49A     P1*1.K=SWITCH(30000,P11.K,TIME.K)
7A      P11.K=AUX6.K-P12.K
41A     P12.K=PULSE(AUX6.K,53,52)
7A      AUX6.K=AUX5.JK+P.JK
49R     AUX5.KL=SWITCH(0,P1*1.K,TIME.K)
6N      AUX5=0
NOTE                                          CHANGE IN DEMAND BETWEEN LAST TWO YEARS
NOTE                                          ***********************************
                                                                          4-1-10
7A      CDFLY.K=TDLY*2.K-TDLY*3.K                                         4-1-11
37B     TDLY=BOXLIN(5,52)
```

```
36N    TDLY=BOXLOAD(9.0000.1)
7A     TDLY*1.K=TDLY1.K-TDLY3.K
41A    TDLY3.K=PULSE(TDLY1.K,53,52)
49A    TDLY1.K=SWITCH(900000,TDLY2.K,TIME.K)
7A     TDLY2.K=STORE.JK+D.JK
49R    STORE.KL=SWITCH(0,TDLY*1.K,TIME.K)
6N     STORE=0
20S    ADLY.K=TDLY*1.K/AP                                               4-1-12
C      AP=52                                                            4-1-13
NOTE                                         DEMAND TOTAL
NOTE                                         ********************************
12R    D.KL=(BD.JK)(EPBD.K)                                             4-1-14
18R    BD.KL=(TWF)(BDJF.JK+BDFF.JK)                                     4-1-15
C      TWF=1.2                                                          4-1-16
58A    EPBD.K=TABHL(DVP,PCR.K,.5,2.5,.2)                                4-1-17
C      DVP*=1.5/1.25/1/1/.95/.9/.85/.8/.75/.7/.65                       4-1-18
20A    PCR.K=PL.K/PLOLW.JK                                              4-1-19
6R     PLOLW.KL=PL.K                                                    4-1-20
NOTE                                         HARVESTING
NOTE                                         ********************************
7R     TACAH.KL=TACAH.JK+TACA2.K                                        4-1-21
41A    TACA2.K=PULSE(TACA1.K,53,52)
7A     TACA1.K=TCRP1.K-TACAH.JK
6N     TACAH=TCROP
1 A    TCRP1.K=(TCROP.K)(1+NF.K)                                        4-1-22
33A    NF.K=(.4)NOISE
35     HPI=BOXCYC(13,HP)                                                4-1-23
C      HPI*=.2/0/.05/.05/.05/.025/.025/0/.116/.117/.342/.2
C      HP=4                                                             4-1-24
44A    H.K=(TACAH.JK)(HPI*1.K)/HP                                       4-1-25
20A    HIR.K=H.K/WFA                                                    4-1-26
C      WFA=1.1                                                          4-1-27
37D    HCI=BOXLIN(6,1)                                                  4-1-28
36     HCI=BOXLOAD(30.00,1)
6A     HCI*1.K=HIR.K
53     THCI.K=SUM1(6,HCI.K)                                             4-1-29
NOTE                                         CROP INVENTORY
NOTE                                         ********************************
51     I.KL=CLIP(I2.K,I1.K,FWG1.K,0)                                    4-1-30
6N     I=80000
14A    I1.K=I.JK.(DT)(HS.K)
7A     HS.K=HIR.K-S.K
7A     I2.K=I1.K.FWG.K
NOTE                                         FRUIT WASTAGE AT GROWER
NOTE                                         ********************************
56A    FWG.K=MAX(FWG1.K,0)                                              4-1-31
12A    FWG1.K=(WDLSG)(DIFF1.K)
C      WDLSG=.4                                                         4-1-32
7A     DIFF1.K=I1.K-THCI.K
7R     TFWG.KL=TFWG1.K-TFWG2.K                                          4-1-33
41     TFWG2.K=PULSE(TFWG1.K,53,52)
7A     TFWG1.K=TFWG.JK+FWG.K
6N     TFWG=0
20     AFWG.K=TFWG.JK/AP                                                4-1-34
```

```
NOTE                                             SALES
NOTE                                             **********************************
56A    S.K=MAX(SS1.K,0)                                                            4-1-35
54A    SS1.K=MIN(MS.K,D.JK)                                    153
20A    MS.K=I.JK/DI                                                                4-1-36
7R     TSGCS.KL=TSGC1.K-TSGC2.K                                                    4-1-37
41A    TSGC2.K=PULSE(TSGC1.K,53,52)
7A     TSGC1.K=TSGCS.JK+S.K
6N     TSGCS=0
20S    ASGCS.K=TSGCS.JK/AP                                                         4-1-38
NOTE                                             PRICE LEVEL
NOTE                                             **********************************
54A    PL.K=MIN(PL2.K,MAXPL)                                                       4-1-39
56A    PL2.K=MAX(PL1.JK,MPL)
C      MAXPL=50^^                                                                  4-1-40
12R    PL1.KL=(PL.K)(DSF.K)
6N     PL1=1000
C      MPL=500                                                                     4-1-42
53A    DSF.K=TABHL(PVD,DSR.K,.55,2.^5,.1)                                          4-1-43
C      PVD*=.65/.7375/.825/.9125/1/1/1.075/1.15/1.225/1.30/1.375/1.45/1.5
X1     25/1.6/1.675/1.75
20A    DSR.K=D.JK/DS.K                                                             4-1-44
4 A    DS.K=SWITCH(1,DS1.K,DS1.K)
20A    DS1.K=I.JK/TT                                                               4-1-45
C      TT=5.5                                                                      4-1-46
NOTE   PROG                                      PROFIT OF ORANGE GROWERS
NOTE                                             **********************************
7R     PROG.KL=PROG1.K-PROG2.K                                                     4-1-47
41A    PROG2.K=PULSE(PROG1.K,53,52)
7A     PROG1.K=PROG.JK+WPOG.K
13A    WPOG.K=(PRFG)(S.K)(PL.K)                                                    4-1-48
6N     PROG=0
C      PRFG=.10                                                                    4-1-49
NOTE
NOTE   COLD STORAGE SECTOR
NOTE
NOTE                                             FRUIT IN COLD STORAGE
NOTE                                             **********************************
51R    MCST.KL=CLIP(MCST2.K,MCST1.K,MWCS1.K,0)                                     4-2-1
6N     MCST=10000
14A    MCST1.K=MCST.JK+(DT)(SSOR.K)
7A     SSOR.K=SIR.K-SOR2.K
20A    SIR.K=S.K/TWF                                                               4-2-2
7A     MCST2.K=MCST1.K-MWCS.K
NOTE                                             MAT WASTED IN COLD STORAGE
NOTE                                             **********************************
56A    MWCS.K=MAX(MWCS1.K,0)                                                       4-2-3
12A    MWCS1.K=(WDLS)(DIFF.K)
7A     DIFF.K=MCST1.K^TSISP.K                                                      4-2-4
C      WDLS=0.2                                                                    4-2-5
37B    SFI=BOXLIN(13,1)                                                            4-2-6
36N    SFI=BOXLOAD(20000,1)
6A     SFI*1.K=SIR.K
53A    TSISP.K=SUM1(13,SFI.K)                                                      4-2-7
C      SP=12
```

```
7R    TMWCS.KL=TMWC1.K-TMWC2.K                                    4-2-8
6N    TMWCS=0
41A   TMWC2.K=PULSE(TMWC1.K,53,52)
7A    TMWC1.K=TMWCS.JK+MWCS.K
20S   AMWCS.K=TMWCS.JK/AP                                         4-2-9
NOTE                                  STORAGE OUTPUT RATE
NOTE                                  ********************************
6R    SOR.KL=SOR2.K                                               4-2-10
7A    SOR2.K=SOR1.K+FCBO.K
54A   SOR1.K=MIN(SOR3.K,D.JK)
7A    SOR3.K=MCST.JK-FCBO.K
37B   SORC=BOXLIN(13,1)                                           4-2-11
36N   SORC=BOXLOAD(16000,1)
6A    SORC*1.K=SOR.JK
53A   TSOSP.K=SUM1(13,SORC.K)                                     4-2-12
NOTE                                  STORAGE OUTPUT BACKLOG
NOTE                                  ********************************
9R    SOB.KL=SOB.JK+D.JK-SOR1.K-FCBO.K                            4-2-13
6N    SOB=0
12A   FCBO.K=(BOMI)(FCBO1.K)                                      4-2-14
54A   FCBO1.K=MIN(MCST.JK,SOB.JK)
C     BOMI=1                                                      4-2-15
NOTE                                  TOTAL STORAGE OUTPUT BACKLOG
NOTE                                  ********************************
7R    TSOB.KL=TSOB1.K-TSOB2.K                                     4-2-16
41A   TSOB2.K=PULSE(TSOB1.K,53,52)
7A    TSOB1.K=TSOB.JK+SOB.JK
6N    TSOB=0
20S   ASOB.K=TSOB.JK/AP                                           4-2-17
NOTE                                  TOTAL COLD STORAGE INVENTORY DURING
NOTE                                  THIS YEAR
NOTE                                  ********************************
7R    TCSI.KL=TCSI1.K-TCSI2.K                                     4-2-18
41A   TCSI2.K=PULSE(TCSI1.K,53,52)
7A    TCSI1.K=TCSI.JK+MCST.JK
6N    TCSI=0
20S   ACSI.K=TCSI.JK/AP                                           4-2-19
NOTE                                  PRICE LEVEL AFTER STORACE
NOTE                                  ********************************
12A   PLAS.K=(SCF*1.K)(PL.K)                                      4-2-20
35B   SCF=BOXCYC(13,4)                                            4-2-21
C     SCF*=1/1.2/1.15/1.15/1.15/1.175/1.175/1.2/1.2/1.084/1.083/1/1
NOTE  PRCS                            PROFIT OF COLD STORAGE
NOTE                                  ********************************
7R    PRCS.KL=PRCS1.K-PRCS2.K                                     4-2-22
41A   PRCS2.K=PULSE(PRCS1.K,53,52)
7A    PRCS1.K=PRCS.JK+WPCS.K
6N    PRCS=0
19A   WPCS.K=(PF)(TROW.K-TPOW.K-TWL.K-_)                          4-2-23
C     PF=0.20                                                     4-2-24
12A   TROW.K=(SOR2.K)(PLAS.K)                                     4-2-25
12A   TPOW.K=(SIR.K)(PL.K)                                        4-2-26
12A   TWL.K=(MWCS.K)(PL.K)                                        4-2-27
```

```
NOTE      JUICE FACTORY SECTOR
NOTE
NOTE                                          FRUIT RECEIVING RATE AT JUICE FACTORY
NOTE                                          ***********************************M
NOTE                                                                                4-3-1
6R     FRRJF.KL=FRRJ1.K
54A    FRRJ1.K=MIN(BDJF.K,SOR2.K)
NOTE                                          BASIC DEMAND FROM JUICE FACTORY
NOTE                                          *******************************
                                                                                    4-3-2
56A    BDJF.K=MAX(AUX20.K,0)
13A    AUX20.K=(OF)(DJTF1.K-MSJF.K)
2 A    DJTF1.K=DJTFR.K/JC                                                           4-3-3
C      OF=2                                                                         4-3-4
C      JC=.5
NOTE                                          FRUIT STORED IN JUICE FACTORY
NOTE                                          *********************************
                                                                                    4-3-6
1L     MSJF.K=MSJF.J+(DT)(FRRJF.JK-CPRJ2.J)
6N     MSJF=125
NOTE                                          DEMAND OF JUICE TINS FROM RETAIL
NOTE                                          **********************************
                                                                                    4-3-7
56A    DJTFR.K=MAX(DJTF2.K,0)
12A    DJTF2.K=(DJTC.K)(EPDJ.K)                                                     4-3-8
12A    DJTC.K=(MDP.K)(SF*1.K)                                                       4-3-8
58A    EPDJ.K=TABHL(DVP,PCR1.K,.5,2.5,.2)                                           4-3-9
20A    PCR1.K=PLCTR.K/PLJT.JK                                                       4-3-10
34A    MDP.K=(1)NORMRN(AVGD.JK,100)                                                 4-3-11
12R    AVGD.KL=(AVGD.JK)(TF)
6N     AVGD=10.0                                                                    4-3-12
C      TF=1.001                                                                     4-3-13
39B    SF=BOXCYC(13,4)
C      SF*=1.1/1./.9/.9/.7/.6/.5/.7/.9/./1.1/1.3/1.1                                4-3-14
6      PLJT.KL=PLCTR.K
NOTE                                          CONC. PRODN. RATE AT JUICE FACTORY
NOTE                                          ********************************
                                                                                    4-3-15
12R    CPRJF.KL=(CPRJ2.K)(JC)
12A    CPRJ2.K=(CPRJ1.K)(JEF)
54A    CPRJ1.K=MIN(MAFJP.K,MR)                                                      4-3-16
C      JEF=.98                                                                      4-3-17
C      MR=1500                                                                      4-3-18
12A    MAFJP.K=(WF)(MSJF.K)                                                         4-3-19
C      WF=.9                                                                        4-3-20
1L     JWCJF.K=JWCJF.J+(DT)(CPRJF.JK-CRJF.JK)
6N     JWCJF=75
NOTE                                          CANNING RATE AT JUICE FACTRY
NOTE                                          ********************************
                                                                                    4-3-21
54R    CRJF.KL=MIN(CPC,JWCJF.K)                                                     4-3-22
C      CPC=1500                                                                     4-3-23
1L     CTJF.K=CTJF.J+(DT)(CRJF.JK-SRRJF.JK)
6N     CTJF=500.
NOTE                                          SALES RATE TO RETAIL FROM JUICE FACTORY
NOTE                                          ***********************************
                                                                                    4-3-24
54R    SRRJF.KL=MIN(DJTFR.K,CTJF.K)                                                 4-3-25
1L     TRS.K=TRS.J+(DT)(SRRJF.JK-SRRS.JK)
6N     TRS=1000
```

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                                              SALES RATE FROM RETAIL STORE
                                              *******************************
SRRS.KL=MIN(TPS.K,DJTFR.K)                                                      4-3-26
                                              PRICE LEVEL OF CANNED TINS FROM RETAIL
                                              *******************************
PLCTR.K=(PFTC)(TCOJT.K)                                                         4-3-27
PFTC=1.30                                                                       4-3-28
TCOJT.K=(OHF)(MC+JCC.K)                                                         4-3-29
MC=100.                                                                         4-3-30
OHF=2                                                                           4-3-31
JCC.K=PLAS.K/JC                                                                 4-3-32
                                              PROFIT ANNUAL
                                              *******************************
PRJF.KL=PRJF1.K-PRJF2.K                                                         4-3-33
PRJF2.K=PULSE(PRJF1.K,53,52)
PRJF=0
PRJF1.K=PRJF.JK+(DT)(AUX7.K)
AUX7.K=(.30)(TCOJT.K)(SRRJF.JK)

   FRESH FRUIT MARKET SECTOR

                                              FRUIT PURCHASING RATE FROM COLD STORAGE
                                              *******************************
FPRCS.KL=SOR2.K-FRRJ1.K                                                         4-4-1
FSDS.K=FSDS.J+(DT)(FPRCS.JK-WSFFR.JK)                                           4-4-2
FSDS=1400.
                                              WEEKLY SALES OF FRESH FRUIT TO RETAIL
                                              *******************************
WSFFR.KL=FPRCS.JK                                                               4-4-3
RSSF.K=RSSF.J+(DT)(WSFFR.JK-RSFC.JK)                                            4-4-4
RSSF=1000
                                              RETAIL SALES TO CONSUMER
                                              *******************************
RSRC.KL=MIN(CDFF.K,RSSF.K)                                                      4-4-5
CDFF.K=MAX(CDFF1.K,0)                                                           4-4-6
CDFF1.K=(BDFF.K)(EPDF.K)
EPDF.K=TABHL(DVP,PCR2.K,.5,2.5,.2)                                              4-4-7
PCR2.K=PLFF.K/PFFLW.JK                                                          4-4-8
PFFLW.KL=PLFF.K                                                                 4-4-9
PLFF.K=(MCF)(PLAS.K)                                                            4-4-10
MCF=1.15                                                                        4-4-11
                                              BASIC DEMAND OF FRESH FRUIT
                                              *******************************
BDFF.KL=(MDFF.K)(SFFFD*1.K)                                                     4-4-12
SFFFD=BOXCYC(13,4)                                                              4-4-13
SFFFD*=.9/.7/.7/.7/.7/.9/1./1.1/1.2/1.3/1.5/1.4/1.
MDFF.K=(1)NORMRN(AVGDF.JK,200.)                                                 4-4-14
AVGDF.KL=(AVGDF.JK)(TF)                                                         4-4-15
AVGDF=15000
PRFF.KL=PRFF1.K-PRFF2.K                                                         4-4-16
PRFF2.K=PULSE(PRFF1.K,53,52)
PRFF=0
PRFF1.K=PRFF.JK+(DT)(AUX1.K)
AUX1.K=(.12)(PLFF.K)(RSRC.JK)
TPROI.K=PROG.JK+PRCS.JK+PRJF.JK+PRFF.JK                                         4-4-17
```

```
PRINT 1)TACAH/2)ACSI/3)ASOB/4)TMWCS/5)AMWCS/6)TDLY*1/7)TPPOI/8)PRFF/9)PR
X     JF/10)PL/11)PLCTR/12)PROG/13)PRCS
PRINT 1)TSGCS/2)ASGCS/3)TDLY*2/4)TFWG/5)AFWG/6)THCI
PLOT  PL=P/PLCTR=L/PLFF=F/PLAS=S
PLOT  P=P/H=H/D=D/S=S/I=I
PLOT  MCST=M/MWCS=W/SOR=O
PLOT  FRRJF=F/BDJF=B/MSJF=M/DJTFR=D/SRRJF=S
PLOT  FPRCS=F/FSDS=S/WSFFR=W/CDFF=C
PLOT  SRRS=S/TRS=T/DJTFR=D/RSSF=F/RSRC=C/CDFF=A
SPEC  DT=1/LENGTH=160/PRTPER=52/PLTPER=4
RUN   BBCAAC
C     TT=5
RUN   BBABAB
C     TT=6
RUN   BBAABC
NOTE  DEMAND DOES NOT EFFECT PLANTING RATE
C     DEP=0
RUN   BBCBAB
NOTE  NO  WASTAGE
C     WDLSG=0
C     WDLS=0
RUN   BBCBAA
NOTE  BACK LOGS ARE NOT MET
C     BOMI=0
RUN   SNKAPR
NOTE  THERE  IS NO TREND IN DEMAND
C     TF=1
```

APPENDIX E

DEFINITION OF MODEL VARIABLES

ACRONYM	DEFNITION	UNITS OF MEASURE	EQUN. NO.
AGRICULTURAL SECTOR			
TCROP	TOTAL ANNUAL CROP	TONS	4-1-1
GP	GROWING PERIO	YEARS	
RFT	RATE OF FRUCTIFICATION OF ORANGE TREES	TONS/WEEK	4-1-2
PPI	PLANTING PERIOD INDEX		4-1-3
FDIC	FACTOR DETERMINING PLANTING DURATION	WEEKS/YEAR	4-1-4
ROTB	RATE AT WHICH ORANGE TREES BECOME BARREN	TONS/WEEK	4-1-5
FP	FRUITING PERIOD	YEARS	4-1-6
P	PLANTING RATE	TONS/WEEK	4-1-7
DEP	DEMAND EFFECT ON PLANTING		4-1-8
CDFLY	CHANGE IN DEMAND FROM LAST YEAR	TONS	4-1-10
TDLY	TOTAL DEMAND DURING LAST YEAR	TONS	4-1-11
ADLY	AVERAGE DEMAND DURING LAST YEAR	TONS	4-1-12
AP	AVERAGING PERIOD	WEEKS	4-1-13
D	TOTAL DEMAND	TONS/WEEK	4-1-14
BD	BASIC DEMAND	TONS/WEEK	4-1-15
TWF	TRANSPORTATION WASTAGE FACTOR		4-1-16
EPBD	EFFECT OF PRICE CHANGE ON BASIC DEMAND		4-1-17
DVP	DEMAND VS. PRICE TABLE		4-1-18
PCR	PRICE CHANGE RATIO		4-1-19
PLOLW	PRICE LEVEL OF LAST WEEK	RS./TON	4-1-20
TACAH	TOTAL ANNUAL CROP AVAILABLE FOR HARVESTING	TONS	4-1-21
NF	NOISE FACTOR		
HPI	HARVESTING PERIOD INDEX		4-1-23
HP	HARVESTING DURATION	WEEKS	4-1-24
H	HARVESTING RATE	TONS/WEEK	4-1-25
HIR	HARVESTED CROP INPUT RATE	TONS/WEEK	4-1-26
WFA	WASTAGE FACTOR AT AGRICULTURE		4-1-27
HCI	HARVESTED CROP IN INVENTORY	TONS	4-1-28
THCI	CROP HARVESTED IN LAST FIVE WEEKS	TONS	4-1-29
I	CROP INVENTORY	TONS	4-1-30
FWG	FRUIT WASTED AT GROWER	TONS/WEEK	4-1-31
WDLSG	WASTAGE FACTOR DUE TO LONG STORAGE AT GROWER		4-1-32
TFWG	TOTAL FRUIT WASTAGE WITH GROWER	TONS	4-1-33
AFWG	AVERAGE FRUIT WASTED AT GROWER	TONS/WEEK	4-1-34
S	SALES RATE	TONS/WEEK	4-1-35
MS	MAX.SALES RATE	TONS/WEEK	4-1-36
TSGCS	TOTAL SALES FROM GROWERS TO COLD STORAGE	TONS	4-1-37
ASGCS	AVERAGE SALES FROM GROWERS TO COLD STORAGE	TONS/WEEK	4-1-38
PL	PRICE LEVEL	RS./TON	4-1-39
MAXPL	MAXIMUM PRICE LEVEL	RS./TON	4-1-40
MPL	MINIMUM PRICE LEVEL	RS./TON	4-1-41
DSF	DEMAND SUPPLY INTERACTION FACTOR		4-1-42
PVD	PRICE VS. DEMAND TABLE		4-1-43
DSR	DEMAND SUPPLY RATIO		4-1-44
DS	DESIRED SALES RATE	TONS/WEEK	4-1-45
TT	INVENTORY TURNOVER TIME	WEEKS	4-1-46
PROG	PROFIT OF ORANGE GROWERS	RS./YEAR	4-1-47
WPOG	WEEKLY PROFIT OF GROWERS	RS./WEEK	4-1-48
PRFG	PROFIT FACTOR FOR GROWERS		

COLD STORAGE SECTOR

MCST	MATERIAL IN COLD STORAGE	TONS	4-2-1
SIR	STORAGE INPUT RATE	TONS/WEEK	4-2-2
MWCS	MATERIAL WASTED IN COLD STORAGE	TONS/WEEK	4-2-3
WDLS	WASTAGE DUE TO LONG STORAGE		4-2-5
SFI	SALE FROM INVENTORY	TONS/WEEK	4-2-6
TSISP	TOTAL SALES FROM INVENTORY DURING SAFE PERIOD	TONS	4-2-7
SP	SAFE PERIOD	WEEKS	
TMWCS	TOTAL MATERIAL WASTED IN COLD STORAGE	TONS/YEAR	4-2-8
AMWCS	AVERAGE MATERIAL WASTED IN COLD STORAGE	TONS/WEEK	4-2-9
SOR	STORAGE OUTPUT RATE	TONS/WEEK	4-2-10
SORC	STORAGE OUTPUT CAR TRAIN		4-2-11
TSOSP	TOTAL STORAGE OUTPUT IN SAFE PERIOD	TONS	4-2-12
SOB	STORAGE OUTPUT BACKLOGS	TONS	4-2-13
FCBO	FRUIT CONSUMED IN BACK ORDERS	TONS/WEEK	4-2-14
BOMI	BACK ORDER MEETING INDEX		4-2-15
TSOB	TOTAL STORAGE OUTPUT BACKLOGS	TONS/WEEK	4-2-16
ASOB	AVERAGE STORAGE OUTPUT BACKLOG	TONS/WEEK	4-2-17
TCSI	TOTAL COLD STORAGE INVENTORY THIS YEAR	TONS/YEAR	4-2-18
ACSI	AVERAGE COLD STORAGE INVENTORY	TONS/WEEK	4-2-19
PLAS	PRICE LEVEL AFTER STORAGE	RS./TON	4-2-20
SCF	STORAGE CHARGES FACTOR		4-2-21
PRCS	PROFIT OF COLD STORAGE	RS./YEAR	4-2-22
WPCS	WEEKLY PROFIT OF COLD STORAGE	RS./WEEK	4-2-23
PF	PROFIT FACTOR		4-2-24
TROW	TOTAL RECEIPTS OF THE WEEK	RS./WEEK	4-2-25
TPOW	TOTAL PAYMENTS OF THE WEEK	RS./WEEK	4-2-24
TWL	TOTAL WASTAGE LOSSES	RS./WEEK	4-2-25

JUICE FACTORY SECTOR

FRRJF	FRUIT RECEIVING RATE AT JUICE FACTORY	TONS/WEEK	4-3-1
BDJF	BASIC DEMAND OF FRUITS FROM JUICE FACTORY	TONS/WEEK	4-3-2
OF	ORDERING FACTOR		4-3-3
JC	JUICE CONTENT		4-3-4
FSJF	FRUIT STORED IN JUICE FACTORY	TONS	4-3-5
DJTFR	DEMAND OF JUICE TINS FROM RETAILERS	TONS/WEEK	4-3-6
DJTC	DEMAND OF JUICE TINS FROM CONSUMERS	TONS/WEEK	4-3-7
EPDJ	EFFECT OF PRICE CHANGE ON DEMAND OF JUICE TINS		4-3-8
PCR1	PRICE CHANGE RATIO -JUICE TINS		4-3-9
MDP	MOVING DEMAND PATTERN OF JUICE TINS	TONS/WEEK	4-3-10
AVGD	AVERAGE DEMAND OF JUICE TINS	TONS/WEEK	4-3-11
TF	TREND FACTOR		4-3-12
SF	SEASONALITY FACTOR		4-3-13
PLJT	PRICE LEVEL OF JUICE TINS IN THE PREVIOUS WEEK	RS./TON	4-3-14
CPRJF	CONCENTRATE PRODUCTION RATE AT JUICE FACTORY	TONS/WEEK	4-3-15
JEF	JUICE EXTRACTION FACTOR		4-3-16
MR	MAX. RATE OF CONCENTRATE PRODUCTION	TONS/WEEK	4-3-17
FAFJP	FRUIT AVAILABILITY FOR JUICE PRODUCTION	TONS	4-3-18
WF	WASTAGE FACTOR		4-3-19
JWCJF	JUICE WAITING FOR CANNING AT JUICE FACTORY	TONS	4-3-20

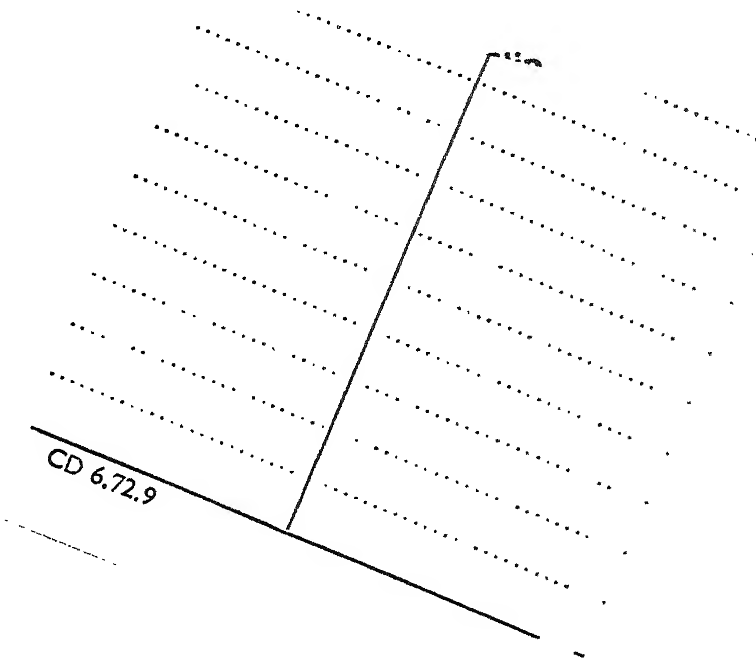
CRJF	CANNING RATE AT JUICE FACTORY	TONS/WEEK	4-3-21
CPC	CANNING CAPACITY	TONS/WEEK	4-3-22
CTJF	CANNED TINS IN JUICE FACTORY	TONS OF JUICE	4-3-23
SRRJF	SALES RATE TO RETAIL FROM JUICE FACTORY	TONS/WEEK	4-3-24
TRS	TINS IN RETAIL STORES	TONS OF JUICE	4-3-25
SRRS	SALES RATE FROM RETAIL STORES	TONS/WEEK	4-3-26
PLCTR	PRICE LEVEL OF CANNED TINS	-SC/T-N	4-3-27
PFTC	PROFIT FACTOR -ON TOTAL COST		4-3 28
TCOJT	TOTAL COST OF JUICE TINS	RS./TON	4-3-29
MC	MANUFACTURING COST	RS./TON(JUICE)	4-3-30
OHF	OVER HEAD FACTOR		4-3-31
JCC	JUICE CONTENT COST	RS./TON	4-3-32
PRJF	PROFIT OF JUICE FACTORY-ANNUAL PROFIT	RS./YEAR	4-3-33

FRESH FRUIT MARKET SECTOR

FPRCS	FRUIT PURCHASE RATE FROM COLD STORAGE	TONS/WEEK	4-4-1
FSDS	FRUIT STOCK FOR DIRECT SALE	TONS	4-4-2
WSFFR	WEEKLY SALES OF FRESH FRUIT TO RETAIL	TONS/WEEK	4-4-3
RSSF	RETAIL SHOP STORE OF FRUIT	TONS	4-4-4
RSRC	RETAIL SALES RATE TO CONSUMER	TONS/WEEK	4-4-5
CDFF	CONSUMER DEMAND OF FRESH FRUIT	TONS/WEEK	4-4-6
EPDF	EFFECT OF PRICE CHANGE ON DEMAND OF FRESH FRUIT		4-4-7
PCR2	PRICE CHANGE RATIO OF FRESH FRUIT		4-4-8
PFFLW	PRICE LEVEL OF FRESH FRUIT LAST WEEK	RS./TON	4-4-9
PLFF	PRICE LEVEL OF FRESH FRUIT	RS./TON	4-4-10
MCF	MARKETING CHARGES FACTOR		4- -11
BDFF	BASIC DEMAND OF FRESH FRUIT	TONS/WEEK	4-4-12
SFFFD	SEASONAL FACTOR FOR FRESH FRUIT DEMAND		4-4-13
MDFF	MOVING DEMAND OF FRESH FRUIT	TONS/WEEK	4-4-14
AVGDF	AVERAGE DEMAND OF FRESH FRUIT	TONS/WEEK	4-4-15
PRFF	PROFIT FROM FRESH FRUIT SALE	RS./WEEK	4-4-16
TPROI	TOTAL PROFIT OF ORANGE INDUSTRY	RS./WEEK	4-4-17

ERRATA

Page	Line	Read	For
15	7	(4)	(3)
27	14	But the ability...	The ability ...
35	8	Reference (16)	Appendix C
63	4 and 5	in Chapter IV	at the end of this Chapter
64	17	Levels-PL, Price level after...	Levels-Price level after...
65	5	remedy	only remedy
66	2	six	four
67	3	six	four
67	12	and	to
67	18	decreasing	increasing
73	22	are	is
74	5	Tables 5.4(a) and 5.4(b)	Tables 5.4 and 5.5
74	14	(Table 5.4(a))	(Table 5.4)
74	19	(Table 5.4(b))	(Table 5.5)
75	9	Some of the parameters	the parameters



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